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Journal of Anatomy and Physiology.

THE FISSURE OF ROLANDO.[1] By D. J. Cunningham, M.D., *Professor of Anatomy and Chirurgery in the University of Dublin.* (Plate I.)

The most complete, and at the same time the most accurate, description of the fissure of Rolando, as it appears in the adult, with which I am acquainted, is that which has been recently given by Dr Oscar Eberstaller of Graz. In the present paper it is my intention to trace the history of this sulcus from its earliest appearance up to the period of its full development. For more than three years I have been collecting material for this purpose; and although I have not succeeded in obtaining specimens which illustrate every stage, I believe that I shall nevertheless be able to present a very nearly complete picture of its growth.

Historical.—The name of "Rolando" was first applied to the fissure in question by Leuret,[3] in 1839, and it has very generally been accepted in France, Italy, and England. At the same time it must be acknowledged that Rolando added little to what was at that time already known of the fissure. He describes the two convolutions[4] between which it lies, and likewise figures it; but many years prior to this it had been figured both by Vicq d'Azyr,[5] and by Gall and Spurzheim.[6] German observers, with the single exception of Pansch, apply to the sulcus the term "Centralfurche," a name which was first

[1] This paper is an abstract of a portion of a memoir which will be shortly published by the Royal Irish Academy—*Cunningham Memoir*, No. vii.

[2] *Das Stirnhirn*, Wien und Leipzig, 1890.

[3] *Anatomie Comparée du Système Nerveux*, Paris, 1839.

[4] "Della Struttura degli hemispheri cerebrali," *In Memorie del reale Accademia della Scienze di Torino*, t. xxv. p. 163, 1831.

[5] *Traité d'Anatomie et de Physiologie*, Paris, 1796.

[6] *Anatomie et Physiologie du Système nerveux en général et du Cerveau en particulier*, Paris, 1810.

introduced by Huschka.[1] If this term be applied to it with the view of indicating its nearly central position with reference to the frontal and occipital poles of the hemisphere, it must be admitted that it is singularly appropriate. But it was not with this signification that it was used by Huschka. Following the views which had been advanced by Leuret, he imagined that the fissure of Rolando passed through the midst of the arching convolutions of the carnivore brain, and separated them into an anterior and a posterior set. The term fissura centralis was founded upon this erroneous view of its homology, and it was owing to this that Pansch so strongly objected to its use.[2]

General Description.—It is customary to describe the upper end of the fissure of Rolando as falling short of the upper margin of the cerebral hemisphere; but, as Eberstaller has pointed out, this is not correct. In 52 hemispheres, taken from children and adults, I found the following:—

(*a*) In 60 per cent. the upper end of the fissure cut the upper border of the hemisphere and appeared on the inner surface.
(*b*) In 21 per cent. it just reached the upper border, but did not show upon the inner surface.
(*c*) In 19 per cent. it fell short of the upper border.

In those cases where the upper extremity of the fissure does not reach the superior margin of the cerebral hemisphere, as well as in those cases where it fairly turns over to reach the inner surface, the sulcus usually ends by bending directly backwards for a distance of about a quarter of an inch or more. On the inner surface of the hemisphere it approaches the upwardly directed end of the calloso-marginal sulcus, but I have never seen it join the latter. Benedikt[3] describes such a union. He says: "In several brains the fissure of Rolando, which in these cases projects far upon the mesial surface, also stands in connection with the fissura calloso-marginalis." Eberstaller also doubts the existence of this connection. In the large number of brains which he has examined, he has never met with an example.

Where the upper extremity of the fissure of Rolando just reaches the upper border of the hemisphere, but fails to turn round it, we do not as a rule see the terminal backward bend which is so characteristic of the two other forms of ending.

In the great majority of cases the lower end of the Rolandic fissure falls short of the fissure of Sylvius. In 19 per cent. of the same 52 hemispheres to which I have already referred, and which comprised a nearly equal number of male and female brains, a shallow connection

[1] *Schädel, Hirn und Seele*, p. 134, Jena, 1854.

[2] *Die Furchen und Wülste am Grosshirn des Menschen*, Berlin, 1879; also "Bemerkungen über die Faltungen des Grosshirns, &c.," *Archiv f. Psychiatrie*, Band viii. p. 244, Berlin, 1878.

[3] *Anatomische Studien an Verbrecher-Gehirnen*, Wien, 1879.

was established. The cases in which this was observed may be classified as follows:—

6 times on the right side.
4 times on the left side.
6 times in the male.
4 times in the female.
6 times in the adult.
4 times in children.

I may further state that although I examined 21 hemispheres of the new-born child, the connection was only present in one instance.

These results are very different from those which have been obtained both by Benedikt and Giacomini. The first of these authorities, in 38 hemispheres found a complete connection between the Rolandic fissure and the Sylvian fissure in eighteen cases, and an incomplete connection in other six.[1] Giacomini,[2] on the other hand, examined 336 hemispheres, and in only 21 of these was the communication present.

Eberstaller gives us what appears to me to be the true explanation of this occasional communication between the fissure of Rolando and the fissure of Sylvius. He points out that in most hemispheres a small variable tertiary furrow may be detected below the lower end of the Rolandic fissure. To this he gives the name of the inferior transverse furrow of the fissure of Rolando. It takes an oblique course upwards and forwards, and is usually separated from the under end of the fissure of Rolando by a superficial gyrus which connects the two central convolutions. Sometimes, however, the fissure of Rolando opens into the inferior transverse furrow, and in such cases the latter may appear as a transverse termination to the main furrow; or should the inferior transverse furrow be in connection with the Sylvian fissure, which it most frequently is, a direct communication between the Rolandic and Sylvian fissures is established. In either case, if the lips of the fissure of Rolando in its lower part be separated from each other, the superficial gyrus which intervenes between the two sulci under ordinary circumstances will be observed pressed down into the bottom. This marks the lower limit of the normal fissure of Rolando. Its shallow onward prolongation into the Sylvian fissure, or the transverse terminal branch, as the case may be, is in reality an additional element—the inferior transverse sulcus of Eberstaller. These facts I can verify in every particular. The connection between the fissure of Rolando and the inferior transverse sulcus is of late occurrence. In only one full-time fœtal hemisphere have I noticed it, and even in this the annectant gyrus was barely concealed within the fissure. On the other hand, at no time can one study more satisfactorily the inferior transverse sulcus than in the two last months of intra-uterine development. It is almost invariably

[1] *Anatomische Studien an Verbrecher-Gehirnen*, p. 96, Wien, 1879.
[2] *Varietà delle circonvoluzioni cerebrali dell' uomo*, Torino, 1882.

present, and it is almost always seen turning round the lower border of the operculum below the lower end of the fissure of Rolando (Pl. I. fig. 7, *a*.).

I believe that where the union between the fissure of Rolando and the inferior transverse sulcus takes place, it usually leads to a direct connection between the former and the fissure of Sylvius. In only four cases have I seen the deep annectant gyrus crossing the bottom of the lower end of the fissure of Rolando without such a connection being established.

In the Chimpanzee the deep annectant gyrus in the lower part of the fissure of Rolando, which indicates a union with the inferior transverse furrow, appears to be usually present. In only one out of four hemispheres in my possession is it absent. In the other three it is strongly marked, and in one of these there is a superficial connection between the fissure of Rolando and the fissure of Sylvius. Even in that hemisphere, in which there is no trace of the deep annectant gyrus, it appears likely that a fusion between the fissure of Rolando and the inferior transverse furrow has taken place, because the sulcus is not any shorter and it reaches as low down as in the case of the other hemispheres. The union, however, is of a more complete kind.

In the Orang, also, I find in two hemispheres a very distinct deep annectant gyrus crossing the bottom of the inferior part of the fissure of Rolando, and partially cutting off a small portion which probably represents Eberstaller's inferior transverse furrow. When I deal with the development of the fissure of Rolando I shall again have occasion to allude to this deep annectant gyrus, and to point out its importance from a morphological point of view.

Between its two extremities the fissure of Rolando pursues a sinuous course. Very seldom in the adult brain is it quite straight. As Eberstaller and others have shown, two of the bends, termed respectively the superior and inferior genua, are more conspicuous than the others. In typical cases these are placed at an equal distance from each other and from the two ends of the sulcus, so that they mark it out into three equal parts. The superior genu is usually much the weaker of the two and is directed backwards. The upper third of the fissure inclines downwards and slightly backwards. At the superior genu the sulcus bends suddenly in a forward and downward direction. The inferior genu is always strongly marked and looks forwards. Here the fissure again changes its direction and proceeds very nearly vertically downwards.

In almost every case the educated eye is able to detect these genua. Perhaps the most common deviation from the condition which we have described as being typical is one in which the central piece of the fissure of Rolando becomes considerably shortened and nearly horizontal in its direction. The two genua are thus more closely approximated, and the inferior may lie almost directly in front of the superior.

We have seen that when the lips of the fissure of Rolando are drawn widely asunder, a deep annectant gyrus is sometimes seen in

its lower part. But this is not the only one which may be present. In the neighbourhood of the superior genu there is generally a marked shallowing of the fissure and a deep interlocking of its adjacent walls. Two of the interdigitating gyri—one projecting backwards from the anterior central convolution and the other forwards from the posterior central convolution—are always larger and more pronounced than the others, and in a considerable number of cases they unite at the bottom of the sulcus in the form of a distinct deep gyrus, which constitutes a marked interruption in its floor. All gradations between a mere shallowing with an interlocking of the adjacent walls of the fissure and the presence of a distinct deep annectant gyrus are met with. This is a point of considerable morphological importance, as we shall see later on.

In five Negro brains in my possession I find the deep annectant gyrus at the level of the superior genu present in each hemisphere. Not only is the condition more distinctly marked than in the European, but in one hemisphere, taken from a young Timanee Negress, the bridging gyrus is so strongly developed that it all but reaches the surface.

In the Chimpanzee this deep annectant gyrus appears to be commonly present. The four hemispheres which I possess show it in a pronounced form in each case. The Orang brain likewise gives evidence of the same condition, but not so distinctly. There is a slight shallowing of the fissure and an interlocking of the adjacent walls, but no distinct bridging gyrus.

In rare cases in the human brain the deep annectant gyrus in question rises completely to the surface and cuts the fissure of Rolando into two separate parts. I have never seen such a condition, although a very close approach to it is observed in one of my Negro brains. Wagner[1] described for the first time such an interruption of the Rolandic fissure in the brain of the celebrated physician Professor Fuchs. Heschl,[2] who examined no less than 2174 hemispheres, only found the anomaly in its complete form six times. Eberstaller met with it twice in 200 brains. It is therefore a condition of extreme rarity.

Development.—The results at which I have arrived regarding the development of the fissure of Rolando are based on the study of thirty-nine hemispheres which I have collected between the fifth and seventh months of development. I have also been supplied, through the kindness of Professor Victor Horsley, with photographs of the series of brain specimens in the Oxford Museum. Several of these show the fissure in its earlier stages.

[1] *Vorstudien zu einer wissenschaftlichen Morphologie und Physiologie des Menschlichen Gehirns als Seelenorgans*, 2 Abh., 1862, Tab. 1, s. 14.

[2] "Die Tiefen windungen menschlichen Grosshirns und die Uberbrückung der Centralfurche," *Wiener Medicinischer Wochenschrift*, 1877, No. 41.

The view which is generally entertained regarding the development of the Rolandic sulcus pictures it beginning as a slight furrow midway between the upper border of the hemisphere and the margin of the Sylvian fossa, and extending gradually and continuously in an upward and downward direction. That it may develop in certain cases this way I do not deny, but I have no direct evidence to show that it does so. In one somewhat advanced hemisphere—belonging to a brain approaching the seventh month—there is certainly an appearance which leads me to believe that the sulcus may have developed in the manner usually attributed to it. It is a clean-cut straight fissure, with its extremities equally distant from the superior border of the hemisphere and the Sylvian region; further, on breaking the hemisphere across in the line of the fissure, the latter is seen to present a uniform depth, and to be at no point interrupted by an elevation of the bottom.

There is some variability in the time at which the fissure of Rolando makes its appearance. The more usual time is the last week or ten days of the fifth month, but it is not uncommon to meet with hemispheres well on in the sixth mouth of development with no sign of the fissure.

As a general rule, the fissure of Rolando is developed in two separate and distinct pieces (Pl. I. figs. 3, 4, 6, r^1 r^2). The lower portion appears in the form of a shallow oblique groove, which represents the lower two-thirds of the fully-formed sulcus. It always makes its appearance before the upper piece (Pl. I. fig. 2). Its lower end is placed close to the coronal suture—perhaps, indeed, it may lie immediately subjacent to the suture—while the upper end lies further back, and reaches a point midway between the upper margin of the hemisphere and the Sylvian fossa. The upper piece of the fissure makes its appearance in the form of a deep pit or depression between the upper end of the lower portion and the margin of the hemisphere. An eminence separates the two portions of the fissure from each other. Soon, however, a faint furrow runs over the summit of this elevated intervening piece of the cortex, and the two primitive portions of the sulcus are partially united to each other (Pl. I. fig. 5, r). As development goes on the more complete does the union become, and the more fully is the intervening

eminence borne down into the bottom of the fissure. As a rule the confluence takes place rapidly, but in many cases the process appears to be retarded. Amongst my specimens I have several hemispheres which, although close upon the seventh month, show still a complete severance of the two constituent elements of the furrow (fig. 6).

But the portion of cerebral cortex which intervenes between the two parts of the fissure is not entirely obliterated. It disappears from the surface, it is true, but it is still to be discerned, even in the adult brain, in the bottom of the fissure, in that shallowing or deep annectant gyrus which we have described at the junction of the upper and middle thirds of the sulcus. In some rare cases, as we have already stated, the two original portions of the fissure of Rolando remain quite distinct throughout life. In these the intervening bridge of cortex remains on the surface, and is not pressed down by the fusion of the upper and lower divisions of the fissure.

We have noted that the same deep annectant gyrus may be observed in the fissure of Rolando of the Chimpanzee and Orang. We may assume, therefore, that the interrupted form of development of this sulcus holds good amongst the anthropoid Apes as well as in Man. With regard to the lower Apes, we have no evidence one way or the other. The development of the fissures in the brain of the Ape is still virtually unknown; and if we examine the bottom of the fissure of Rolando and the other primary furrows in a low Ape we find a uniform depth throughout, and an absolute absence of deep annectant gyri. It is dangerous to argue from the adult condition alone, but still the appearances are such as would lead us to infer that the continuous and not the disrupted form of development of the primary fissures holds good amongst the lower Apes.

In Man and in the anthropoids the development of the fissure of Rolando is in every respect on a line with that of the other two radial "Primärfurchen" (viz., the praecentral and the intraparietal), the only differences being that it is unprovided with a horizontal part, and that its two vertical portions rapidly fuse with each other. In the case of the praecentral sulcus, the two vertical parts (viz., the praecentralis inferior and the praecentralis superior,) as a general rule remain apart. The intervening piece

of cerebral cortex remains on the surface. The two vertical pieces of the intraparietal sulcus, on the other hand, usually run together, as in the case of the fissure of Rolando. In 26 per cent., however, of cerebral hemispheres they remain distinct; whereas the non-union of the two pieces of the Rolandic sulcus occurs in only 0·3 per cent.

But in Man, as we have observed, a third lower element may be added to the Rolandic fissure in the shape of the inferior transverse sulcus of Eberstaller. In the anthropoid Ape the connection of this element with the main furrow appears to be much more intimate than in Man. Of course, in Man it cannot be placed on the same footing as the other two elements, seeing that it appears so much later (eighth month), and that it may establish other connections besides that with the Rolandic sulcus.

As I shall point out further on, the fissure of Rolando is very much longer in the anthropoid Ape than in Man. If we represent the length of the fissure of Rolando in the human brain by the number 100, we find that in the Chimpanzee it is 130, and in the Orang 120. It appears to me, therefore, not improbable that this lower element, so variable and inconstant in its present connections, may have had at one time a closer association with the fissure of Rolando in Man. In all the anthropoid hemispheres in my possession, with one exception, the lower piece of the fissure of Rolando is partially cut off by a deep annectant gyrus.

It is not uncommon to find the lower piece of the praecentral fissure developed in the earlier part of the fifth month, prior to the appearance of the fissure of Rolando. I have six hemispheres which show this condition, and under these circumstances the praecentral sulcus is very apt to be mistaken for the fissure of Rolando. Its position in front of the middle of the hemisphere and in front of the coronal suture should, in all cases, enable us to detect its true nature (fig. 1, *p.c.i.*). At the same time, I may mention that it was not until I had obtained two hemispheres belonging to this early period, in which the fissure in question was strongly marked, and in which also there was a slight trace of the fissure of Rolando, that I was thoroughly satisfied as to its identity. I have never seen the

third radial "Primärfurche" or intraparietal sulcus appear before the Rolandic sulcus.

The inferior genu of the fissure of Rolando always makes its appearance before the superior genu. About the seventh month it is usually well marked. This is exactly what one might expect, seeing that amongst the lower Apes the inferior genu alone is, as a rule, developed. In one specimen this genu is quite distinct upon the inferior piece of the fissure before it has joined the upper piece (fig. 3, r^1). As a general rule, however, the fissure remains straight until the union of its two elements is complete. The superior genu is developed at the point of junction, and it is not until a later period that it assumes any degree of prominence.

The upper end of the fissure of Rolando does not overstep the upper border of the hemisphere until the beginning of the last month of intra-uterine development. In the eighth month it just reaches the margin, and I have several specimens which show it in the process of turning over and in the process of developing the backward bend of its upper extremity.

From the seventh month onwards the growth of the two bounding banks of the fissure does not proceed at an equal pace. There appears to be a greater growth-energy in the posterior central convolution, and this leads to a partial overlapping of the ascending frontal convolution by the ascending parietal convolution. Heschl and Eberstaller have called attention to this. It is more obvious in the lower two-thirds of the fissure, or, in other words, opposite that portion of it which is formed by the lower element. It is owing to this that the adult fissure cuts into the cerebral surface in an oblique direction from before backwards.

Topography.—Since the time when Broca[1] in France, Turner[2] in this country, Hefftler[3] in Russia, and Bischoff[4] in Germany demonstrated the relation of the cerebral fissures and convolu-

[1] Sur le siége de la faculté du langage articulé," *Bull. de la Soc. Anatomique*, 1861.

[2] "On the Relations of the Human Cerebrum to the Outer Surface of the Skull and Head, *Jour. Anat. and Phys.*, 1873.

[3] "Izviliny golovnavo mozga ou tchelovieka i otnochenia ich k'svodou tcherepa," *Dissertation inaugurale chirurgicale à l'acad. med. chir. de St Petersburg*, 1873.

[4] *Die Grosshirnwindungen des Menschen*, &c., Munich, 1868.

tions to the surface of the cranium, an enormous amount of work has been done in this department of anatomy. Foulhouze [1] first called attention to the conditions which exist in this respect in children, and he was followed in this field by Féré,[2] Symington,[3] and others. The two latter observers have also made some observations on the position of the fissure of Rolando in the fœtus.

As a rule, each observer, in determining the position of the various cerebral sulci, has adopted a method of his own. In France, Broca's plan of introducing pegs through the cranium into the cerebrum, and then removing the brain, has been almost universally adopted. Bischoff independently employed the same means. Turner and Hefftler examined the brain *in situ*—a proceeding which is certainly very much to be preferred. Symington, and to a certain extent Féré, arrived at their conclusions by sections through the frozen head.

In my endeavours to arrive at accurate results regarding the topography of the fissure of Rolando, I have employed several different methods; but throughout the entire investigation I have recognised that the most reliable measurements could only be obtained from the brain while still within the cavity of the cranium. It would be impossible on the present occasion to indicate with any degree of detail the methods which I have pursued. In the case of fœtal brains, I removed in the first instance the parietal bone and subjacent dura mater on one side, and then mapped out the area on the surface of the cerebrum covered by this bone by inserting small pins at short intervals from each other. Féré adopted very much the same plan, but as he only sought to determine the absolute distance of the fissure of Rolando, the parieto-occipital fissure, and the Sylvian fissure from the coronal, lambdoid, and squamous sutures, he made his measurements on the fresh head. When the pins were accurately adjusted, I transferred the entire head into a chloride of zinc bath and afterwards into alcohol. This plan gave admirable results. Of course the cerebrum was considerably reduced in bulk, but the shrinkage was uniform; and as it was relative and not absolute results I desired, the diminution in bulk was not a matter of any consequence.

In the case of children and adults, models were made of the head, with the brain exposed *in situ*, by the method described in a previous number of this *Journal*.[4] Latterly some important modifications

[1] *Recherches sur les Rapports Anatomiques du Cerveau avec la voute du Crane chez les enfants*, Paris, 1876.

[2] Amongst a number of important papers published by Féré, we may specially mention, as bearing particularly on the present research, "Sur le développement du cerveau considéré dans ses rapports avec le crane," *Revue d'Anthr.*, 1879.

[3] *Topographical Anatomy of the Child*, Edinburgh, 1887.

[4] "Proceedings of the Anatomical Society," *Jour. Anat. and Phys.*, vol. xxii., April 1888, p. xiii.

upon the plan as it was originally described were adopted, but it is unnecessary to go into these at present. Twenty-eight models of the human head and of the head of the Ape were in this manner prepared, but it was a very laborious undertaking, and could only be carried out on a comparatively small number of individuals. It was therefore found to be necessary to supplement the facts obtained in this way by others acquired by a less lengthy process.

In dealing with young subjects and young Apes, in which the sutures are open, and in which, along the lines of union between the bones, the dura mater and periosteum stand in direct connection, I found that by simply removing the calvaria the pattern of the coronal and lambdoid sutures could easily be detected on the surface of the dura mater. Small pins were introduced into the cerebrum along these sutural lines, and the brain was either hardened *in situ* without removal of the dura mater, or it was at once extracted and plunged into a chloride of zinc bath.

There is still another plan which afforded excellent results. One half of the cranial vault was removed with the saw by a vertical cut a little to one side of the mesial plane, and a transverse cut a short distance below the highest point of the squamous suture. The cerebral hemisphere of that side was then removed, and the head placed so that it rested upon the opposite side. The falx cerebri was next detached, and the mesial surface of the hemisphere still in position exposed. Upon this it was easy to recognise the upper end of the fissure of Rolando from its position in relation to the upturned extremity of the calloso-marginal sulcus. The point at which the fissure of Rolando turns over the upper margin of the hemisphere being determined, a peg was here driven through the skull from within outwards and the remaining hemisphere removed. The falx cerebri was then stitched back in its place, so as to give the proper amount of tension to the tentorium, and a cast of the interior of the cranium taken. The peg, which projected slightly into the interior of the cranium, marked on the cast the position of the upper end of the fissure of Rolando, and before drawing the cast the sutural lines were mapped out on its surface by driving an awl through the skull at short intervals. The great disadvantage of this method is that it only gives us information regarding the topography of the fissures along the upper margin of the hemisphere.

But it was impossible to note the sutural relations in every instance. Time would not allow of it. A large number of my measurements have consequently been made upon brains removed from the cranial cavity. In every case, however, they have in the first instance either been carefully hardened *in situ* or plunged at once into a chloride of zinc bath, and thus fixed in their natural shape.

The points in the topography of the fissure of Rolando which I have chiefly endeavoured to arrive at are the following:—

1. The relative distance of the upper extremity (*a*) from the anterior end of the cerebrum, (*b*) from the coronal suture.
2. The relative distance of the lower extremity (*a*) from the anterior end of the cerebrum, (*b*) from the coronal suture.

To express these relations clearly, it is necessary to construct four indices, which may be respectively termed the mesial fronto-Rolandic, the mesial corono-Rolandic, the lateral fronto-Rolandic, and the lateral corono-Rolandic. In calculating the mesial indices the length of the upper margin of the hemisphere, measured by the tape from its anterior to its posterior end, is taken as the standard, and equal to 100; and in the case of the lateral indices the length of the cerebrum measured over its lateral surface between the same points is taken as the standard and equal to 100.

But in determining the length of the cerebrum, either along its upper border or its lateral surface, it is absolutely essential that the points between which the measurements are taken should be rigidly adhered to throughout, and it is by no means an easy matter to select points which are in every respect satisfactory. Eberstaller measures from the inner angle of the trigonum olfactorium to the point where the occipital lobe first touches the tentorium. There cannot be a doubt that this is a good method, and one which is calculated to give accurate results; but both of his points are on the under surface of the brain, and consequently it is impossible to adopt his plan when the brain is being measured *in situ*. I have been forced therefore to select different points from which to make my measurements. In front I fixed upon a point which corresponds to the level of the outer part of the superciliary margin of the frontal lobe. This border is very far from being horizontal. Its outer part is on a much higher level than the inner part. As it is traced inwards it is seen to take a sudden curve downwards towards the cribriform plate of the ethmoid bone, where it merges with the mesial border. A line drawn horizontally inwards from the high outer part of the superciliary border of the frontal lobe cuts the mesial border of the cerebrum at the point which I arbitrarily selected as the anterior end of the cerebrum. It lies, as a rule, just below the most projecting

part. Behind I took the most prominent part of the occipital pole.

The upper end of the fissure of Rolando presented another difficulty. As we have noted, this usually cuts the upper border of the hemisphere, and I have always measured to the point at which it reaches this margin. But there are cases in which it falls short of the upper border of the hemisphere, and then it usually bends suddenly backwards for a short distance. In these cases I have measured to the angle of bending, and my reason for selecting that point is simply this: that even when the fissure reaches the mesial surface of the hemisphere we, as a general rule, see the same backward inflexion of its extremity, and the angle of bending corresponds with the point where it cuts the upper border of the hemisphere.

The following Table gives the average results of my measurements:—

Topography of the Fissure of Rolando in the Human Cerebrum.

	Age.	Number of Hemispheres Measured.	Mesial Indices.		Lateral or Lower Indices.	
			Fronto-Rolandic.	Corono-Rolandic.	Fronto-Rolandic.	Corono-Rolandic.
Intra-uterine Life.	5½–6½ months,	8	51·2	9·9	41·8	5·6
	6½–7½ ,,	6	52·9	11·9	43·2	3·6
	7½–8½ ,,	17	54·6	17·2	42·8	9
	Full-time fœtuses, .	18	53·5	18·2	42·6	10·7
Extra-uterine Life.	3 months, .	5	52·8	18·6	43·3	12·8
	6 ,, .	4	50·6	14·4	42·2	8·6
	12 ,, .	3	50·6	13·6	42·3	5·1
	4–5 years, .	14	52·6	16·5	43·3	11·3
	11–15 ,, .	6	51·8	16·1	42·3	8·8
	Adults, . .	37	52·7	16·7	43·3	12·9

The corono-Rolandic distance was not measured in every case, and therefore the average results for the corono-Rolandic indices which are given above are not based upon so large a number of measurements as in the case of the fronto-Rolandic indices.

This Table speaks for itself, so that little need be said about the various items which compose it. One point is very remark-

able, and that is the constancy in the position of the fissure of Rolando on the surface of the cerebrum throughout all stages of growth. It will be seen on glancing at the fronto-Rolandic indices that the changes which it undergoes in its position from the time that it first appears on the surface of the cerebrum up to adult life are very slight indeed. Its lower end, as might be expected from the fact that it is first formed, shows the slightest change. As development and growth proceed it moves back slightly, but only to an almost inappreciable extent. When it first appears the lower fronto-Rolandic index is 41·8, but in a few weeks it soon establishes its proper relations, and from this time on it fluctuates between 42·2 and 43·3. These fluctuations can hardly be regarded as indicating differences of position at different periods of growth. If larger numbers of brains were examined, I am satisfied that they would disappear altogether.

The upper end of the fissure of Rolando is not so fixed in its relations at different periods of life. From the time that the fissure first appears there seems to be a tendency for the upper end to move backwards. At first the upper fronto-Rolandic index is 51·2. This increases steadily until the full period of intra-uterine life is nearly reached, when it is found to have mounted up to 54·6. No doubt this is brought about by an accelerated growth of the upper part of the frontal lobe during the period of the change. From the time of birth up to the third month the upper end of the fissure of Rolando moves in the opposite direction until the index of 52·8 is reached, and here it remains fixed. This is the position which I believe it holds ever afterwards. I do not lay any importance on the low indices seen in the Table in connection with the 6 months', 12 months', and 11 to 15 years' hemispheres. The number measured was too small to allow us to base any generalisation upon the indices which they afford us.

The position of the fissure of Rolando to the coronal suture at different periods of growth must next engage our attention. This is expressed in the series of upper and lower corono-Rolandic indices in the foregoing Table. We have seen that the position of the fissure of Rolando on the surface of the brain is subject to very slight alterations, and that in all probability we may consider that it becomes absolutely fixed at the third

month of extra-uterine life. Very different, however, are its relations to the coronal suture at different periods in its history. The figures obtained, it is true, are somewhat puzzling and difficult to interpret, but one point is perfectly clear, and it is this:—The parietal bone and the area of brain immediately subjacent do not grow at an equal pace. In the early stages of its development the fissure of Rolando lies close to the coronal suture, but this does not mean that it lies far forward on the brain, but simply that the parietal bone forms at a later stage a relatively greater extent of the cranial vault. The maximum amount of the frontal lobe (the district in front of the fissure of Rolando) covered by the parietal bone is reached at the third month of extra-uterine life. The upper corono-Rolandic index at this period is 18·6 and the lower 12·8. From this stage on the coronal suture in its upper part falls back a little, and after a slight oscillation it assumes, at the fourth or the fifth year of childhood, a fixed position with reference to the fissure of Rolando. This is expressed by the index 16·5. The lower end of the suture shows changes in its position with reference to the fissure of Rolando which are less easy to understand. I can hardly believe that the oscillations which are exhibited in the lower corono-Rolandic indices give expression to the usual growth changes. To arrive at the standard of growth, a much larger number of heads would require to be examined than I have had at my disposal. One point, however, is rendered evident, viz., that the relative position of the coronal suture to the lower end of the fissure of Rolando is subject to very considerable variations.

Before leaving this branch of my subject it is necessary to take note of the work which has been done in the same field by Hamy, Foulhouze, Féré, and Symington.

In an article published in 1872, Hamy makes the following extraordinary statement:[1]—"Chez de jeune enfants dont la ligne suturale qui vient d'être nommé différait assez peu dans son inclinaison de celle de l'adulte, nous avons constaté que le sillon de Rolando *passait en avant* de l'articulation, de telle sorte que l'os frontal, dans ses parties laterales et inférieures, se trouvait recouvrir une petite étendue du lobe pariétal." This supposed forward position of the lower end of the fissure of Rolando he seeks to associate with the feeble development in the infant of the third frontal convolution. It is all the

[1] *Revue d'anthropologie*, p. 428.

more necessary to contradict this statement, seeing that Schwalbe appears to give some credence to it and has given it a place in his standard work on "Neurologie" (p. 575). As we have noted, the fissure of Rolando at no stage of its development lies in front of the coronal suture. In two instances I have seen the lower end just touching the sutural line, but these were cases in which it was in its earliest stage, prior to the development of its upper piece.

Foulhouze examined a large number of subjects of different ages, but although he brings out many important details in connection with the cranio-cerebral topography of the child, he only gives us absolute measurements, and consequently they have little bearing upon the present research. Féré, also, in a paper already quoted, furnishes us with much valuable information regarding the topography of the fissure of Rolando. He refuses to believe the views put forward by Hamy, and states that in all cases the fissure of Rolando lies behind the coronal suture. He only gives absolute measurements, and he seems to regard the coronal suture as being more fixed in its position than the fissure of Rolando. Symington was also led to doubt the accuracy of Hamy's statements.

I shall now give a Table which shows the position of the fissure of Rolando in the Ape, both in relation to the cerebral surface and the cranial wall. I have in my possession a very large series of facts in connection with this branch of the inquiry, but on the present occasion I limit myself to the anthropoid Ape, and only introduce one of the lower Apes for purposes of comparison.

Topography of the Fissure of Rolando in the Ape.

	Hemispheres Examined.	Upper Indices.		Lower Indices.	
		Fronto-Rolandic.	Corono-Rolandic.	Fronto-Rolandic.	Corono-Rolandic.
Chimpanzee,	4	55·7	16	39·2	7·5
Orang,	4	55	20·7	39·2	11·1
Hamadryas,	1	50	13·3	42·1	5·2

Briefly stated, the following are the more interesting points which are brought out by this Table:—(1) In the Hamadryas the position of the Rolandic fissure, both in its relation to the cranium and the surface of the cerebrum, approach those seen in the early stages of the development of the fissure in Man.

(2) In the anthropoid Apes the upper part of the frontal lobe is more extensive, whilst the lower part is less extensive than in Man. (3) In the Chimpanzee the upper corono-Rolandic index is in accord with the corresponding index in Man, whereas in the Orang it is very different.[1]

Huschka, in his remarkable work entitled *Schädel, Hirn und Seele*, published in 1854, contends that marked sexual differences can be detected in the human cerebrum. He asserts that in the male a relatively greater mass of the hemisphere lies in front of the fissure of Rolando, whilst in the female a greater mass lies behind it. To use his own words—"Das weib ist ein *homo parietalis* und *interparietalis*, der Mann ein *homo frontalis*." Rüdinger[2] gives expression to somewhat similar views. He insists strongly upon the early appearance of sexual differences in the brain of the fœtus and newborn child, and specially mentions that "in the majority of male fœtal brains the frontal lobes appear more massive, broader, and higher than in the female." More recently Passet,[3] under the direction of Rüdinger, returns to the subject, and gives the results which he has obtained from an extended series of brain measurements. He comes to the conclusion "that the fissure of Rolando, relatively as well as absolutely, lies farther back in the male than in the female—or, in other words, that more brain matter lies in front of the fissure of Rolando in the male than in the female." He considers, however, that Huschka has somewhat overstated the sexual differences. Passet illustrates his views by a very ingenious diagram.

Eberstaller has gone into this question, in so far as it concerns the adult, with his usual care and thoroughness. He measured no fewer than 270 hemispheres (viz., 94 female and 176 male), and he found that the upper end of the fissure of Rolando occupies relatively the same place in the two sexes; what difference there is (0·5) is in favour of the female frontal lobe. It is to be regretted that he gives no measurements which would enable us to locate the lower end of the sulcus in the two sexes.

The results which I have obtained for the adult brain agree in every respect with those of Eberstaller, and I would add to

[1] I should mention here that I have measured six Chimpanzee hemispheres, and in four of these determined the corono-Rolandic indices. Two of the latter I have not introduced into the above Table on account of the very anomalous relationships which the fissure of Rolando presented. I shall not describe these at present, but merely state, that on both sides the fissure of Rolando was placed very much in front of its usual position. Further, its lower end lay in front of coronal suture. This brain will afterwards be described in full.

[2] *Über die Unterschiede der Grosshirnwindungen nach dem Geschlecht beim Fœtus und Neugeborenen*, München, 1877.

[3] "Ueber einige Unterschiede des grosshirns nach dem Geschlecht," *Archiv f. Anthrop.*, May 1882.

what he has stated—(1) that the lower end of the fissure of Rolando also holds relatively the same place on the cerebral surface in the two sexes; and (2) that at no period of growth does the fissure of Rolando exhibit in its position what we might safely regard to be sexual differences.

The following Table gives the relative position of the fissure of Rolando at different periods of life in the two sexes:—

Topography of the Fissure of Rolando in the Two Sexes.

Males.					
Age.	Number of Hemispheres Examined.	Upper Indices.		Lower Indices.	
		Fronto-Rolandic.	Corono-Rolandic.	Fronto-Rolandic.	Corono-Rolandic.
7½–8½ months,	5	54·5	16·3	44·2	9·6
Full-time fœtuses, .	14	53·5	18·1	42·6	11·1
4–5 years, .	8	52·3	16	43·1	10·1
Adults, . .	17	52·6	16	43·7	12·1

Females.					
Age.	Number of Hemispheres Examined.	Upper Indices.		Lower Indices.	
		Fronto-Rolandic.	Corono-Rolandic.	Fronto-Rolandic.	Corono-Rolandic.
7½–8½ months,	12	54·6	17·8	42	8·7
Full-time fœtuses, .	4	53·7	18·5	42·8	9·6
4–5 years, .	6	53·8	17·6	43·8	13·7
Adults, . .	20	52·9	17·5	43	13·9

Eberstaller, as we have mentioned, has shown that in the adult, if there is any sexual difference, it is one in favour of the frontal lobe of the female. It is curious to note that the above Table shows the same in each period of growth, but the differences are extremely trifling. This is interesting in the light of what we have already noted in connection with the upper end of the fissure in the anthropoid Ape. But there is one point

which this Table brings out which appears to me to be a matter of some importance. It will be seen that the area of the frontal lobe covered by the parietal bone is relatively greater in the female than in the male. The corono-Rolandic index shows this. The fissure of Rolando is therefore situated at a relatively greater distance from the coronal suture than in the male.

Rolandic Angle.—By the "Rolandic angle" I mean the angle which is formed by the meeting of the upper end of the sulcus with the mesial plane. If we were to divide a cerebral hemisphere into an anterior and posterior portion along a line stretching from the point where the sulcus oversteps the upper border of the hemisphere to the lower end of the fissure, the angle which would then be formed by the cut surface of the anterior segment and the mesial surface would constitute the Rolandic angle.

Several authors have sought to establish a sexual distinction by means of this angle. Huschka remarks: "On an average the fissure of Rolando, with its bounding central convolutions, stands more perpendicularly in the female than in the male." Rüdinger says: "The more transverse direction of the fissure of Rolando, and the bounding central convolutions, appears in the female fœtal brain a striking arrangement. But as the oblique direction of the central convolutions in the female fœtal brain, and the transverse in the male, likewise occur, I might provisionally entertain the supposition that these differences might be produced less through sex than through differences in the shape of the head." His pupil, Passet, is less cautious, and states dogmatically that "the angle which the fissure of Rolando forms with the mesial plane is greater in the female and approaches more nearly to a right angle than in the male; in other words, the male fissure of Rolando, on an average, courses somewhat more obliquely from above downwards and outwards than in the female." This author represents the average male angle to be 60°·9, and the average female angle as 64°·2. More recently Dr Josef Victor Rohon,[1] another worker in the laboratory of Professor Rüdinger, goes so far as to assert that the same sexual distinction in the angle of Rolando may be detected in the Chimpanzee.

Giacomini gives the angle of the fissure of Rolando as varying from 57°·5 to 62°·5, whilst Hare,[2] who measured it *in situ*, found it to vary from 60° to 73°, the average being 67°. Eberstaller, on the other hand, who examined no less than 300 hemispheres, states that the Rolandic angle varies from 70° to 75°, and that he could discover no sexual difference in this respect.

[1] *Zur Anatomie der Hirnwindungen bei den Primaten*, München, 1884.

[2] "The Position of the Fissure of Rolando," *Jour. Anat. and Phys.*, vol. xviii. p. 717.

To measure this angle correctly is a matter of very great difficulty, and therefore we need not be surprised that the various authors I have quoted should have arrived at such divergent results. A very simple instrument, which I had constructed for the purpose, enabled me, I believe, to measure the angle accurately. The following are the results I obtained:—

Rolandic Angle.

	Age.	Number of Hemispheres.	Average Angle in Males and Females.	Males.			Females.		
				Number of Hemispheres.	Average Angle.	Average Cephalic Index.	Number of Hemispheres.	Average Angle.	Average Cephalic Index.
Intra-uterine Life.	$5\frac{1}{2}$–$6\frac{1}{2}$ months,	8	73°·6	...	...	...	...	...	...
	$6\frac{1}{2}$–$7\frac{1}{2}$,,	6	73°·5	...	...	...	...	...	...
	$7\frac{1}{2}$–$8\frac{1}{2}$,,	16	70°·8	5	74°·4	...	11	69°·3	...
	Full-time fœtuses, .	16	70°·6	13	70°·1	...	3	73°	...
Extra-uterine Life.	First 12 mths,	9	70°·6	...	...	...	9	70°·6	76·2
	4– 5 years, .	5	70°·6	4	70°	77·7	1	73°	81·5
	11–15 ,, .	7	70°·1	4	71°·2	76·1	3	69°	74
	Adult, . .	8	71°·7	3	73°·6	79·7	5	71°·7	74
	Chimpanzee, .	4	68°	...	...	...	...	...	...
	Orang, . .	4	68°	...	...	...	...	...	...
	Hamadryas, .	1	71°	...	...	...	...	...	...

From the above Table it would appear that the average Rolandic angle may be regarded as being 71°. The results which I have obtained in this respect closely correspond with those stated by Eberstaller. Further, it will be observed that this angle is attained as early as the eighth month, and is maintained from this period up to adult life—another remarkable instance of the fixity of the fissure of Rolando, once its preliminary development is fairly established. In the first two months of its existence the Rolandic fissure presents a more open angle with the mesial plane. It traverses the surface of the hemisphere in a more transverse direction (73°·6), and this is quite in keeping with what we have already stated as to its topography. Hamy, in a paper already referred to, contends that in the young subject the Rolandic angle is only 52°, whilst

in the adult it is 70°, and he seeks to associate this with the development of the third frontal convolution. It is needless to say that there is no foundation whatever for this statement.

Nor is there anything in the angle of the fissure of Rolando by which we could establish sexual distinctions. I quite agree with Eberstaller in this. The above Table shows differences, it is true, but the increase or diminution of the angle is as often found on the one side as the other. How can we account for these? Rüdinger was not far from the truth when he hinted that the form of the head might have some influence in this direction. Any one who studies the average cephalic indices which I have introduced into the table will see that the angle increases and decreases with the rise and fall of the cephalic index. In brachycephalic heads the angle is more open than in dolichocephalic heads. In the first twelve months of extra-uterine life all the specimens I possess are females. Collectively they present the average angle of 70°·6, but if we analyse the various items which go to form the whole, we find three hemispheres with an average angle of 67°·7, and the unusually low cephalic index of 71, whereas the others gave an average angle of 73° and an average cephalic index o f 79.

It is right to state that the results obtained by Mr Hare do not coincide with this view, and from the fact of his measurements having been made upon the brain *in situ* I attach a high importance to them. In five dolichocephalic heads the average angle was 68°·6, whilst in six brachycephalic heads it was 66°·6.

Length of the Fissure of Rolando.—Passet has endeavoured to prove that the fissure of Rolando is both relatively and absolutely longer in the male than in the female, and Rohon believes that the same sexual distinctions may be detected in the Chimpanzee. The absolute length of the fissure is of no importance, because this will vary with the absolute size of the brain, and therefore the increase in length in the male is what might naturally be expected. In order to get at the relative length, it is necessary to have some standard wherewith we may compare

[1] Welcker, Broca, and Calori hold that the head of the female is more dolichocephalic than that of the male. If this be the case, we would expect to find a more acute Rolandic angle. Weisbach, Arnold, and Mantegazzi, on the other hand, consider that it is the male head that shows the greatest amount of dolichocephaly.

it. As the most convenient standard I have taken the total length of the hemisphere measured by the tape along its superior border. This we shall regard as being equal to 100. The fissure was measured by a thread introduced between the lips of the fissure and following accurately all its flexures.

My results are very different from those obtained by Passet. It appears to me that three circumstances affect the length of the fissure:—(1) the depth of the portion of the cerebrum which lies above the Sylvian fissure; (2) the degree of flexuosity of the fissure; and (3) the union or non-union of the fissure with the inferior transverse furrow of Eberstaller. The following are my results:—

Length of the Fissure of Rolando.

Age.		Number of Hemispheres.	Average Relative Length (Male and Female).	Males.		Females.	
				Number of Hemispheres.	Average Relative Length.	Number of Hemispheres.	Average Relative Length.
Intra-uterine Life.	5½–6½ months,	8	16·7	...	...	...	...
	6½–7½ ,,	6	25·1	...	...	...	...
	7½–8½ ,,	10	35·4	2	29·7	8	36·8
	Full-time fœtuses, .	11	32·8	10	33	1	31
Extra-uterine Life.	First 12 mths,	8	35·8	...	...	8	35·8
	4– 5 years, .	7	33·9	5	33·4	2	38·5
	11–15 ,, .	6	36·1	4	33·7	2	38·9
	Adult, . .	30	39·3	14	38·6	16	40·1
	Chimpanzee, .	4	51·1	...	...	...	...
	Orang, . .	4	47·2	...	...	...	...
	Hamadryas, .	1	41·1	...	...	...	...

There are several points brought out by this Table which at present I do not pretend to understand, and consequently I shall not enter into them; but it is clear that if there is any sexual distinction in the length of the fissure, it is quite in the opposite direction from that stated by Passet and Rohon.[1] The

[1] In all probability it will be shown that the length of the fissure is greatly affected by the shape of the head. I have material in my possession for determining this point, but as yet I have not had an opportunity of working it up.

great relative length of the anthropoid fissure is very remarkable. This is partly explained by the fact that in the anthropoid Ape there is relatively more brain substance above the fissure of Sylvius than in man, in the proportion of 73 to 68. Further, the anthropoid fissure is more flexuous.

EXPLANATION OF PLATE I.

The figures in this plate have been drawn on the stone directly from photographs. Fig. 7 is considerably reduced; the others are the size of nature.

Fig. 1. Lateral surface of right hemisphere in the earlier part of the fifth month. The area of the parietal bone is indicated by shading. The inferior praecentral fissure (*p.c.i.*) is in position, and simulates the fissure of Rolando. Note its position in front of the coronal suture. *e.p.*, external perpendicular fissure of Bischoff.

Fig. 2. Lateral surface of a hemisphere approaching the sixth month of development. The lower piece of the fissure of Rolando is developed, and lies entirely behind the coronal suture. Area of the parietal bone indicated by shading.

Fig. 3. Lateral surface of a left hemisphere approaching the seventh month of development. The two pieces in which the fissure of Rolando is developed (r^1 and r^2) are well seen. The lower piece (r^1) is seen in the form of a groove, in which the inferior genu is already developed; whilst the upper piece (r^2) shows in the form of a pit. *p.*, intra-parietal sulcus of Turner; *p.c.i.*, sulcus praecentralis inferior; *p.c.s.*, sulcus praecentralis superior.

Fig. 4. Right hemisphere at a stage of development slightly in advance of that shown in fig. 3. Lettering the same.

Fig. 5. Hemisphere close upon the seventh month. It shows the stage in the development of the fissure of Rolando where the two pieces of the sulcus have united. Still a shallowing at the place of union may be seen. The area of the hemisphere covered by the parietal bone is indicated by shading. *r.*, fissure of Rolando; *p.c.*, sulcus praecentralis; *p.*, intra-parietal sulcus of Turner.

Fig. 6. Hemisphere close upon the seventh month of development. From a photograph of a specimen in the Oxford Collection. r^1, lower piece of the fissure of Rolando; r^2, upper piece of the sulcus of Rolando; *p.c.i.*, praecentralis inferior; *p.c.s.*, praecentralis superior; f^1, superior frontal; *p.*, intra-parietal sulcus of Turner; p^1, ramus verticalis inferior; p^3, ramus horizontalis; p^4, ramus occipitalis; *e.p.*, external perpendicular fissure of Bischoff; *p.l.*, parallel sulcus.

Fig. 7. Hemisphere between the eighth and ninth months of development. From a photograph of a specimen in the Oxford Collection. *a.*, inferior transverse furrow of Eberstaller.

MALFORMATION OF THE FEMALE ORGANS OF GENERATION—VAGINA DUPLEX ET UTERUS DUPLEX—ASSOCIATED WITH DISPLACEMENT OF THE RIGHT KIDNEY. By DAVID HEPBURN, M.B., F.R.S.E., *Senior Demonstrator of Anatomy, University of Edinburgh.*

AT almost any stage in their progress the processes of normal development may become partially or completely arrested, and as a result abnormalities or malformations are produced. Hence it is that the study of development and the study of malformations afford each other mutual assistance, for, while the former provides us with the true explanation of the latter, the latter may give us the key to some difficult problem in connection with the former. From this standpoint all malformations deserve careful study. Especially is this the case in connection with malformations of the genito-urinary system, for there are still many points in its development which require solution. Apart from these considerations, were any further reason necessary to warrant the recording of the following observations, it would be found in the comparative rarity of the occurrence of this malformation of the female generative organs, for, notwithstanding the numerous cases on record,[1] the present is the only instance which has been seen in the University Anatomy Department during the last thirty years.

The subject was reported to be about 35 years of age. She had been for some time a field-worker in connection with a workhouse, and, so far as her antecedents were known, she had never been pregnant. In the dissecting-room the appearances of parts at once attracted attention when the subject lay in the lithotomy posture. The following notes were made as the dissection proceeded:—

External Genitals (fig. 1).—The labia majora were of normal development, but the labia minora appeared somewhat smaller

[1] Kussmaul, *Von dem Mangel, der Verkümmerung und Verdopplung der Gebärmutter*, 1859.

than usual, and their posterior diverging ends became lost in the vaginal wall at a greater distance from the surface than is usually the case. The vestibular area had become incorporated with the general surface of the anterior vaginal wall, and thus the orifice of the urethra, instead of forming an elevated papilla at the base of the vestibule, merely showed itself as an opening on the flat surface of the anterior vaginal wall. The mucous lining of the vagina was smooth, and presented no traces of *carunculæ myrtiformes*, and there was no hymen. The subjoined measurements refer to the foregoing statements:—

Length of vulvar orifice, from junction of labia majora to posterior commissure, . .	75 mm.
Length of labia minora from junction above clitoris, ...	35 „
Length of true perineum, . . .	16 „
Distance of urethral orifice from glans clitoridis, ...	24 „
Distance of urethral orifice from a plane extending between glans clitoris and the posterior commissure, ...	6 „

At the bottom of the vaginal tube, which was scarcely an inch in depth, two secondary openings were seen. Each of these was of oval outline, and they were situated laterally, forming right and left openings, separated from each other by a partition whose greatest width between the two openings was 5 mm. The nearest point of each orifice was 15 mm. distant from the urethral opening. The two openings of the secondary vaginæ were placed obliquely, their anterior ends being farther from the mesial plane than their posterior ends. The distance between their anterior ends was 20 mm., between their posterior ends 10 mm. In both, the greater length was obliquely from before backwards,—the right measuring 17 mm., the left 14 mm.; and the shorter diameter from side to side, the right measuring 10 mm. and the left 6 mm. It will thus be seen that the right orifice was larger in both diameters than the left. As already mentioned, there was no hymen and no apparent trace of one, and therefore it is extremely interesting to note that each of

the orifices just described was partly guarded by a crescentic valve-like flap. In the case of the right opening this flap was associated with its *anterior* end, and the deepest part of the crescent projected 10 mm. from its attached border; at the left opening a similar flap was attached round the *posterior* end, and projected 7 mm. from the wall.

Exploration by the tip of the little finger revealed the presence of a septum placed in the antero-posterior plane between the two secondary vaginæ. No cervix uteri could be felt projecting into either tube, and in neither could an os uteri be localised by the finger, although in each case a body of firmer consistence than the vaginal wall was felt.

A close watch was kept upon the dissection of the abdomen, but nothing noteworthy was observed until the posterior abdominal wall was reached, when it was found that the right kidney was abnormally placed.

It occupied the posterior part of the right iliac fossa, resting upon the psoas and iliacus muscles, and obscuring the bifurcation of the right common iliac artery. Its outline was that of a flattened ovoid body, the long axis being parallel to the long axis of the trunk. The base of the mesentery was attached obliquely across the anterior surface of the kidney, the lower half of which projected free over the pelvic brim.

The anterior surface of the organ was very irregular and mostly occupied by the hilus, from which the ureter and renal brim emerged and two renal arteries entered. The ureter was situated nearer the mesial plane than the renal vein, and both occupied a position between the two renal arteries entering the hilus.

The renal arteries to this right kidney were four in number—two arising from the abdominal aorta and two from the right common iliac artery.

(*a*) From the abdominal aorta two—an upper and a lower.

The upper arose 6 cm. above the bifurcation of the aorta —higher than the inferior mesenteric artery. It was obliquely outwards and downwards in front of the inferior vena cava, passing beneath the renal vein and entering the kidney through the highest part of its circumference. A small offset from this artery travelled

downwards over the anterior surface of the kidney under cover of the renal vein, and entered at the hilus.

The lower arose $2\frac{1}{2}$ cm. above the bifurcation of the abdominal aorta, midway between that point and the origin of the inferior mesenteric artery. Its course was nearly horizontally outwards, to reach the margin of the kidney, and thereafter it ran in a furrow on the anterior surface of the organ, descending obliquely to the hilus, where it entered. The principal renal vein occupied the groove alongside of this artery.

(*b*) From the right common iliac artery two—an upper and a lower.

The upper arose from the outer aspect of the common iliac opposite its commencement. It ran outwards in front of the lower part of the inferior vena cava upon the psoas muscle and behind the kidney, the posterior surface of which it pierced near to its outer margin.

The lower arose from the pelvic aspect of the common iliac close above its termination. It entered the lower end of the kidney close to its margin.

Close beside this artery a vein was found. It emerged from the lower end of the kidney, and ran towards the mesial plane, where it opened into the middle sacral vein, near the junction of the latter with the left common iliac vein.

The principal renal vein, as already indicated, emerged from the hilus in three rootlets, which united to form a vessel of the usual calibre. Near the upper end of the kidney it received tributaries from the right uterine broad ligament, and thereafter pursued an oblique course upwards and inwards to join the inferior vena cava.

The ureter arose from a small infundibulum formed by the union of three divisions, which appeared independently at different parts of the hilus. It entered the pelvis in the usual way, and ran towards the base of the bladder under cover of the posterior false ligament of the uterus.

External Appearances of the Uterus and its Appendages.—The left ovary and left Fallopian tube were normally associated with their broad ligament, and lay within the cavity of the true pelvis.

The right ovary and the fimbriated end of the right Fallopian tube occupied a position in the right iliac fossa, being fixed in that region by peritoneal attachments, and lying close to the outer side of the lower half of the displaced right kidney. The left ovary was larger than the right, and presented a much more cicatrised surface. Each Fallopian tube occupied the highest part of the broad ligament, and each underwent a sudden increase in size, indicating the commencement of the uterine cornua. The length of the left Fallopian tube, from the small end of the trumpet-shaped extremity to the uterine cornu, was 9½ cm.; the right Fallopian tube, between corresponding points, measured 16 cm.

The uterine cornua became approximated together to form the corpus uteri, which was covered on its anterior and posterior aspects by peritoneum, the serous covering being rather more extensive on the posterior surface.

The sacrum, coccyx, and part of the postero-lateral walls of the pelvis were next removed, and an uninterrupted view of the viscera obtained from behind. The peritoneal covering was stripped off in the region of the pouch of Douglas, and the rectum carefully detached from the posterior wall of the vagina as low down as the perineal body. A finger was thereafter inserted into each vagina from the vulvar orifice, and a longitudinal incision made through the posterior wall of each tube. The walls were thin at the lower parts, but they increased in thickness towards the upper parts. The septum between the two canals was perfect, and entirely separated the one from the other. In both tubes the mucous membrane was thrown into transverse folds or rugæ. In neither was there any indication of a cervix uteri; indeed, each ended as a *cul-de-sac* or digital fossa, on the *septal side* of which there was an opening—that of the left side being large enough to admit a crow-quill, while the right was almost a pin-hole orifice, and admitted a fine blowpipe. Air could readily be injected at both orifices, and it did not pass from one cornu to the other, but merely inflated the side along which it was driven. In this way there was evidence of two distinct cavities in the corpus uteri—a body which measured 38 mm. (1½′) from the external uterine orifices to the fundus, where the uterine horns separated from each other. A

director was placed in each uterine cavity, and each was opened along its whole length by a posterior incision. The separation between the two cavities was complete. For an inch they lay side by side, their walls being dense and comparatively thick, and in this portion their interiors presented, on a small scale, the characteristic arbor vitæ of the cervix uteri, and the lumen of each cavity was greater than the diameter of the orifice which led into it from the vagina, or out of it into the cavity of the uterine cornu (fig. 2).

From the two internal uterine orifices the uterine cavities diverged from each other, the angle so formed between them being filled with solid tissue for about half an inch.

The cavity of each cornu when inflated resembled a small finger—5 cm. (2 inches) in length—and then it suddenly narrowed down to become continuous with the Fallopian tube of its own side. The round ligaments had their customary attachments.

We have therefore before us the persistence of an early fœtal condition, in which the ducts of Müller have remained distinct from each other throughout their entire length, and the fusion which should have taken place between them is limited to an approximation of the ducts in those regions which represent the cervix uteri and the greater length of the vaginal canal. The crescentic folds which are found at the orifices of the double vagina may be regarded as indicating the lateral rudiments of a hymen, and pointing to its formation at the junction of Müller's ducts with the urogenital sinus.

While it is not my intention to give a detailed account of the literature on this subject, or to institute comparisons between the present case and those already recorded, still I may mention the principal sources of authentic information. Kussmaul, in his important work *Von dem Mangel, der Verkümmerung und Verdopplung der Gebärmutter*, 1859, summarises the subject to that date. Afterwards Fürst adds other cases, "Ueber Bildungshemmungen des Uterovaginalkanales, *Monatsschrift für Geburtskunde*, Bd. xxx. s. 97 und 161. More recently Ahlfeld revises the subject in *Die Missbildungen des Menschen*, 1880. He is of opinion that such cases occur very frequently, and says he has seen four or five instances in women otherwise

well formed. He notes that such abnormalities are most commonly associated with ectopia vesicæ, and concludes that the lower end of the bowel has projected forwards between the ducts of Müller, and thereby prevented their fusion, although the same result may follow a tumour such as the allantois pressing upon the ducts of Müller from the front.

For the drawings which illustrate this paper I am indebted to my friend and pupil, Mr Edward Leaming.

Fig. 1.

Fig. 2.

THE VALUE OF NERVE-SUPPLY IN THE DETERMINATION OF MUSCULAR HOMOLOGIES AND ANOMALIES.[1] By D. J. Cunningham, M.D., *Professor of Anatomy and Chirurgery, University of Dublin.*

The Heidelberg School of Anatomy is responsible for the theory that a muscle is to be regarded as the end-organ of a nerve, and that if we succeed in recognising the latter, we have in our hands a sure and infallible means of determining the homology of the former. This view, which was first advanced by Gegenbaur, and which has been maintained and elaborated with so much ability by his pupils Fürbringer and Ruge, has exercised for some ten years or more a marked influence upon morphological work.

Prior to its enunciation, investigations into the comparative anatomy of the muscular system were conducted in a very unsatisfactory manner, and the great majority of the papers which were written on the subject contained little more than dreary catalogues of origins and insertions with haphazard hints as to homologies.

One writer, indeed, in this country—the late Professor Rolleston—in his well-known observations upon the serial homologies of the muscles in connection with the shoulder and pelvic girdles, had employed the nerve-test with marked success, but in the determination of ordinary homologies it was customary to rely solely upon a consideration of the position and attachments of a muscle.

But whilst there cannot be a doubt that the nerve of supply is the best and safest guide to follow in our endeavours to trace the history of any muscle or group of muscles, and that it will, in the vast majority of cases, lead us to right conclusions, there is grave reason for the belief that it is not an absolutely infallible guide.

Nine years ago, at the meeting of the International Medical

[1] This communication was the opening statement in the discussion on this subject in the Section of Anatomy and Physiology, British Medical Association, Birmingham, July 1890.

Congress in London, I discussed this matter, and brought forward some facts in support of the opinion which I have just expressed. Since then much has been written on the subject, and the present appears to be a convenient time for reviewing the evidence which has been advanced on both sides.

A proper solution of the problem can only be obtained by approaching the question from two points of view:—(1) by studying the early connections which exist between the nervous and muscular systems in the embryo; (2) by examining one or more groups of muscles, the homologies of which are undoubted, in a large series of different animals, or in a large number of individuals of the same species, and observing whether in every case the nerves of supply are the same.

Fürbringer, in his great work upon the "Morphology of the Bird," has reviewed at considerable length, and, it must be admitted, in a very impartial spirit, the embryological aspect of the question. He puts before us three possibilities in regard to the neuro-muscular connection.

1. Do the ganglion cells, nerve-fibres, and muscle-fibres, which constitute the neuro-motor apparatus, present a loose and changeable combination of originally independent elements?

2. Does the apparatus present in its fully formed state a real and unchangeable unity—a unity, however, which is only brought into existence by the *secondary* union of originally separate nerve and muscle elements?

3. Does it represent an apparatus which is formed out of the same elements, so that ganglion cells, nerve-fibres, and muscle-fibres not only present a community of origin, but also an original and indissoluble union?

The epiblastic origin of the nerves and the mesoblastic origin of the muscles would appear to be absolutely established by the writings of Balfour, Marshall, His, and Kölliker, and if this be the case the last of these views is altogether untenable. And there is little use in taking shelter behind the statement made by Hensen, viz., that no one in ontogeny has ever seen the free growing end of a nerve-fibre, because here the observations of Professor Paterson may be appropriately cited. In his important investigations into the "Fate of the Muscle Plate," Mr Paterson has traced the formation of the nerves as

they spread out from the spinal nerve-trunk into the limb, and he has shown that they are built up of epiblastic elements foreign to the limb and distinct from the mesoblast which forms the muscles.

With regard to the precise manner in which the neuro-muscular connection takes place, we have few observations to go upon. Two observers, Calberla and Bremer, have dealt with the question. Both maintain that it is a secondary union of originally separate elements, but they are at variance with each other as to the actual manner in which the union is brought about. Calberla holds that the extra-muscular nerve-fibre becomes united to an intra-muscular end-organ. Bremer, on the other hand, asserts that the connection is brought about by a growth of the whole nerve-fibre, including its end-organ and sheath, to the muscle-fibre.

But it is needless to pursue this aspect of the question further. The theory that nerve and muscle present a community of origin appears to be contrary to what we are in the habit of regarding as well-established fact.

It now remains for us to discuss the two other possibilities put forward by Fürbringer regarding the neuro-muscular connection. Is the secondary connection which is established of a loose and changeable kind, or is it fixed and unalterable? To say that the relation is a loose one would be to infer that variations in nerve-supply are of frequent occurrence, which is certainly not the case; whereas, on the other hand, to affirm that the relationship is unalterable, and not only holds good for the past and the present, but will also hold good for the future, lands us in this difficulty, that variations in nerve-supply are undoubtedly met with, not only in the homologous muscles of different animals, but also in the case of the same muscle in different individuals of the same species.

Of course it may be held that what appears to be a variation in nerve-supply may not in reality be so; that in fact we are merely dealing with a case where certain nerve-fibres have adopted a different path to reach their destination, and although the connection be a secondary one, yet *the same ganglion cells* are invariably connected with the *same muscle-fibres*. A great deal may be said for this view, and, considering the constancy of

the relation between muscle and nerve, it must be regarded as a perfectly legitimate opinion to hold. At the same time in many cases it is incapable of proof, because when once nerve-fibres forsake the path they are accustomed to follow, their identity is extremely difficult to establish. Outside the spinal cord it may be done, and no doubt is frequently done, but when the transference takes place inside the cord, as, for example, by a group of fibres coming out at a higher or lower level, it is almost impossible to recognise them with any degree of certainty. The nerve to the subclavius may perhaps be quoted as an example of nerve-deviation within the spinal cord. As a rule this little twig comes out with the 5th spinal nerve, but, as Dr Brooks has pointed out, it may emerge a stage higher up with the 4th spinal nerve.

Every anatomist has observed examples of transference of nerve-fibres, during their course outside the spinal cord, from a familiar to an unfamiliar route. Several years ago I called attention to the connection which exists between the varying magnitude of the communicating loop which usually passes from the 2nd to the 1st dorsal nerve, and the varying size and range of distribution of the intercosto-humeral and lesser internal cutaneous nerves, and in the light of this Professor Wilson, of Sydney, has been able to explain what at first sight appears to be a discrepancy in the nerve of supply of the "achsel-bogen" muscle, and indeed to localise it in the 2nd dorsal metameric segment. In some instances the "achselbogen" muscle receives its nerve of supply from the intercosto-humeral, but in other cases it comes from the internal anterior thoracic or the lesser internal cutaneous nerve of Wrisberg. In all cases the source from which the fibres are derived is the same. They come from the 2nd dorsal nerve. In the one case they pass directly to the muscle through the intercosto-humeral nerve; in the other cases they follow the tendency exhibited by all limb nerves, viz., they enter the plexus before they finally pass to their destination.

The accessory phrenic and the accessory obturator are other examples of nerve transference, and Sir William Turner has recorded two very striking cases in which the long buccal nerve proceeded from the superior instead of the inferior maxillary

division of the 5th nerve.[1] Many other instances might be given, but those that I have quoted are sufficient to show, what indeed is a matter of common knowledge to every teacher of anatomy, viz., that nerve-fibres outside the spinal cord do not in every case follow the same paths as they travel towards their different destinations.

Both muscles and the nerves which are associated with them are arranged in groups, and it is where these come into contact with each other that there is a tendency exhibited for one or other of the nerves to overstep the boundary line and extend its territory at the expense of its neighbour.

In dealing with this question on a former occasion, I chose the intrinsic muscles of the foot and the two plantar nerves for the purpose of testing the value of nerve-supply in the determination of muscle homologies. No better ground could be found, because here we have a series of muscles which are easily and readily identified. We may fairly assume that the muscles attached to any particular digit are homologous with the muscles connected with the corresponding digit in all animals.

Amongst the large number of different mammals which I examined, I only encountered four in which there was a decided deviation from the ordinary typical distribution of the plantar nerves. In three of these, viz., the Elephant, Hyrax, and Beaver, the internal plantar nerve invades the territory of the external plantar and seizes upon muscles which usually do not belong to it. The Fox-bat affords an example of the opposite kind; the external plantar lays hold upon a muscle which in the typical condition is under the sway of the internal plantar. I need not enter further into particulars, but I may be allowed to mention that, by the appearances presented, I was led to consider that the muscular distribution of the internal plantar nerve has in all probability been more extensive at one time than it is now. It is possible that at one time the two plantar nerves took an equal share in the intrinsic muscle supply of the foot. The hand and foot of the Hyrax present a condition which approaches very nearly to this. Judging from the arrangement in the Fox-bat, there appears to be a tendency for the external plantar nerve to drive the internal plantar nerve out of the field altogether.

[1] *Proc. Roy. Soc. London*, 1868, p. 456, and *Jour. Anat. and Phys.*, Nov. 1866.

This struggle for supremacy, as it were, between two contiguous nerves supplying contiguous groups of muscles, opens up an interesting field for work, and Dr Brooks has recently pointed out that the same contest may be observed in the hand, between the corresponding nerves, viz., the ulnar and median. In some cases the ulnar, and in other cases the median, may be observed to gain ground.

But in these cases of variation in the nerve supply of the intrinsic muscles of the hand and the foot we are dealing with nerves which come off from the same plexus, viz., the plantar nerves from the sacral plexus, and the median and ulnar nerves from the brachial plexus. Further, Mr Herringham has shown that the fibres which enter into the formation of the inner head of the median and the ulnar nerve, are derived as a rule from the same spinal nerves. Certainly, therefore, these cases of nerve-deviation in the supply of the hand and foot muscles cannot be held as furnishing us with absolute proof against the hypothesis of an unchanging and unalterable connection between the ganglion cells and muscle-fibres, because they can satisfactorily be explained by supposing a slight deviation from the path followed by certain of the nerve-fibres.

One circumstance, however, militates somewhat against this view. Mr Herringham, in his elaborate dissections of the brachial plexus, has satisfied himself that the intrinsic muscle nerve-fibres of the median come from the 6th, or the 6th and 7th spinal nerves, and travel downwards through the outer head of the median, whilst the corresponding nerve-fibres of the ulnar come from the 8th or the 8th and 9th spinal nerves. The nerve-transference then, if there be any, is thrown back into the spinal cord.

But examples are not wanting in which there is a substitution of the ordinary nerve of supply, by one which comes from a different nerve-plexus. Ruge, the distinguished Professor of Anatomy in the University of Amsterdam, furnishes us with a striking instance of this. Thus, in the Ornithorhynchus, the tibialis anticus and the inner part of the extensor longus hallucis are supplied by a branch from the anterior crural nerve, which is prolonged downwards to its destination over the external condyle of the femur. Ruge is a firm believer in the immuta-

bility of nerve-supply, and this is an awkward case for him to bring into reconciliation with his views. He assumes that the muscles concerned are not homologous with the similarly named muscles in other mammals, but belong rather to the extensor muscles of the thigh. He further believes that the fibres, which in the leg are supplied by the anterior crural, are gradually abolished, and that their place is taken by others derived from the external muscles of the leg, which drag their nerve of supply along with them.

With one part of this hypothesis I entirely agree, viz., that the innervation of these muscles points to their original derivation from the extensor muscles of the thigh; but I cannot accept the other part of the theory, viz., that the muscles thus derived are afterwards replaced by others similarly situated and similarly attached. It is much more reasonable to suppose that the distribution of the peroneal nerve is extended so as to include all the extensor muscles of the leg; that, in other words, the peroneal nerve invades the territory of the anterior crural in the same manner that the external plantar nerve encroaches upon the domain of the internal plantar nerve.

This supply of leg muscles by the anterior crural nerve, in a case where the leg muscles at the knee-joint are almost completely segmented off from the extensor muscles of the thigh, must be regarded as the persistence of a very archaic condition. Professor Humphry and Dr Brooks have shown that in cryptobranchus, and menobranchus there is a continuity over the knee-joint of the extensor muscles of the thigh and leg, by means of flattened tendons, and yet all the extensors of the leg are supplied by the peroneal nerve. In these two forms, therefore, we have a continuous muscle sheet, and a discontinuous nerve-supply; whilst in the Ornithorhynchus we have a break in the continuity of the muscles, but a continuous nerve-supply.

Dr Gadow furnishes us with several examples of the same muscle being supplied by a nerve from a different plexus in different animals. Thus, he has pointed out, that in the Iguana the ischio-femoral muscle is supplied by the ischiadic plexus; in the Crocodile it is supplied by the obturator nerve; while in Varanus it is supplied by both. And he very justly remarks that if we did not know the condition in the Monitor, the nerve

of supply in the other two cases would be more likely to lead us astray than to help us in our endeavours to determine the homology of the muscle in question.

He endeavours to explain this deviation by supposing that the muscle is composed of different factors in each case.

I presume that the ischio-femoral muscle to which Dr Gadow refers is the adductor magnus of mammalian anatomy. If this be so it is interesting to note that we meet with somewhat corresponding variations in its nerve-supply amongst mammals, and seeing that it lies as it were in the interval between the extensor and flexor groups of muscles, this need not be a matter for surprise. The typical supply of the adductor magnus in Mammalia is, as in the Monitor, a double one from the obturator nerve and the sacral plexus. In marsupials, however, as in the Iguana, the nerves of supply are derived solely from the sacral plexus. That the condition is not a stable one, is shown by the interesting case recently recorded by Prof. Wilson, in which he noticed in a human subject a tendency for the ischiadic nerve-filaments to extend beyond their confines, and usurp a portion of the muscle which is usually held by the obturator.

Other examples of homologous muscles being supplied by nerves which come from different parts of the spinal cord in different animals might be given, but those which I have cited are sufficient for our purpose. The question, therefore, now comes to be: How can these decided nerve-deviations be accounted for? Three very different explanations may be offered, viz., by supposing—

1. A complete obliteration, and then a reconstruction of both muscle and nerve elements—the muscles assuming the position and attachments of their predecessors. It is in this way that Ruge accounts for the disappearance of the archaic form of nerve-supply to which we have referred in the leg of the Ornithorhynchus.

2. A retention of both nerve and muscle elements, but by the adoption of a new and more convenient path by certain of the nerve-fibres. This view receives considerable support from the fact, that the great majority of apparent deviations from the typical nerve-supply, can be more or less satisfactorily shown to be due to nerve-transference.

3. A retention of the muscle elements, but a substitution of new nerve-elements.

The first of these hypotheses I reject *in toto*. It would indeed be a curious caprice of development if muscles once formed, and in every respect competent, were abolished to give place to others similar in position and attachments. But again, in the cryptobranchus and menobranchus, we have the clearest proof that the primitive extensors of the leg are not abolished, although they have got rid of their archaic nerve-supply. Extensors of the leg and extensors of the thigh are in direct anatomical union with each other.

With regard to the two last hypotheses I am not prepared to advocate either of them very strongly to the disadvantage of the other. Those who have worked chiefly at the lower vertebrates, will probably incline most to the view that the same ganglion cells are invariably connected with the same muscle-fibres, and that deviations in nerve-supply are merely to be regarded as deviations in the path chosen by the nerve-fibres. At the same time, I hardly think that this explanation is capable of accounting for every case of deviation in nerve-supply. I am inclined to believe that in some cases we may have a real substitution of new for old nerve-elements. Mr Paterson's researches would seem to indicate not only the possibility, but even the probability, of such a change occasionally taking place.

But notwithstanding all this I agree with Fürbringer, when he says that the nerve of supply is "the most important and indispensable guide for the determination of muscle homologies." It is not an absolutely infallible guide, however, and in rare cases it might lead the observer astray.

And if the nerve of supply be valuable as a means of determining muscular homologies, it must be equally so in deciding upon the true nature of a muscular anomaly. It is upon this ground that I hold so strongly that the musculus sternalis is to be regarded *in all cases* as a portion of the pectoralis major. Its nerve of supply from the thoracic nerves has now been traced by seven independent observers in no less than forty-six cases. Twenty-nine of these cases occurred in my own department, and I maintain that this is the invariable and constant supply

of the sternalis. That, along with its true thoracic supply, there may in rare cases be associated a min from one or other of the intercostal twigs is proved by Shepherd, but that this should ever constitute its sole supply, as Professor Bardeleben asserts (more especial states in eleven consecutive cases), I simply cannot beli

A CONTRIBUTION TO THE PHARMACOLOGY OF CURARE AND ITS ALKALOIDS. By JOSEPH TILLIE, M.D., *Assistant to the Professor of Materia Medica in the University of Edinburgh.* PARTS III. and IV. (PLATE II.)

(*Continued from* vol. xxiv. (N.S. vol. iv.) p. 516.)

PART III.

The Action of Curarine on the Blood-Pressure.

THE study of the actions of pure curarine on the circulatory apparatus promises to explain those uncontrollable disturbances in blood-pressure which have been by some recorded as accompanying the use of crude curare in experiments. No clear rule for the action of the arrow-poison on the circulation could ever be laid down, because the poison itself remained a variable factor. Many investigations have been made with the crude poison, especially by *Traube* (1) and by *Von Bezold* (2) in 1863, and later by *Latschenberger and Deahna* (3), *Grützner and Heidenhain* (4), *Vulpian* (5), *Bœhm* (6), *Gaskell* (7), *Bernstein* (8), *Kobert* (9), *Waters* (10), *Bowditch and Warren* (11), *Ellis* (11), *Couty and De Lacerda* (12), and others. Many interesting results were obtained, and frequent reference is made to them in physiological literature.

In connection with physiological observations on the innervation of the blood-vessels some interesting and unusual statements are made about curare by *Latschenberger and Deahna* (3), and by *Grützner and Heidenhain* (4). The former found that certain curares immediately acted on the circulation as if they contained strychnine, and that after the administration of other curares, which had not this immediate strychnine-like action, some rabbits were so sensitive—although paralysed and artificial respiration maintained—that it was impossible to obtain a regular blood-pressure tracing. The last-mentioned authors observed, in experiments on rabbits, that, with four

different kinds of curare, small doses caused a reflex stimulation of the vasomotor centres, so that sudden and marked rises of blood-pressure followed very slight stimulation of the skin. No such effects could be produced in non-curarised rabbits.

I shall now state the results of my own experiments, made in Leipzig, with exact doses of the pure alkaloid. In all some thirty-seven blood-pressure experiments were made on rabbits, cats, and dogs—chiefly on rabbits.

By intravenous injection the minimum complete motor-paralysing dose of curarine for the rabbit was found to be about 0·0002 gramme per kilogramme of body-weight. The action of this dose, under artificial respiration, only continues during a few minutes. After 0·0003–0·0005 grm. the movements of the diaphragm and the reflexes return, on an average, in 10 to 15 minutes, after 0·001 grm. in 15 to 30 minutes, and after doses of 0·001–0·005 grm. in from 30 to 90 minutes and longer.

In rabbits slight convulsive movements occur just before motor paralysis is complete, usually 15 or 20 seconds after the injection of small doses of curarine (0·001–0·002 grm.) has been begun. These spasms occur although artificial respiration is fully maintained during the injection, and they are very probably due to the tetanising action of the poison on the spinal cord.

The injection of watery solutions of curarine into the blood-vessels (either an artery or a vein) of rabbits, cats, or dogs causes, as a rule, an almost immediate fall of blood-pressure, and successive injections during the same experiment produce the same result.

When the dose is small or medium (1 to 20 times the minimum paralysing dose) the fall of blood-pressure is temporary, and the original level of pressure at least is usually recovered in from ½ to 10 minutes. But, in rabbits especially, the initial fall of pressure may be followed almost immediately by a rise above normal, and, if the dose be injected slowly, the fall may not be observed, or may be very slight.

When the dose is very large (from 50 to 100 times the minimum paralysing dose) the immediate decrease of pressure is marked, of long duration, and the original level of pressure is not usually regained.

Some examples of the amount and duration of the fall of blood-pressure which immediately follows the intravenous injection of different doses of curarine are given below in Table I. An exceptionally marked case (Cat), considering the smallness of the dose, is shown among the facsimiles of the original tracings at the end of the paper (Pl. II. fig. 1). Fig. 2 (Pl. II.) shows the depression of blood-pressure in a rabbit.

TABLE I.

Animal.	Number of Dose and Amount in Grammes.	Blood-Pressure at Time of Injection in mm.	Lowest Pressure reached in mm.	Maximum Amount of Fall of Pressure in mm.	Time after Injection before Maximum Depression reached.	Time after Injection before Pressure again attained (often only for brief period) Original Level.
Cat .	1st. 0·001	176	42	134	2¾ min.	3 min.
	2nd. 0·002	156	122	34	40 sec.	6 "
	3rd. 0·003	140	54	86	3 min.	Remained for 10 min. at 54 mm. and then quickly returned to 140 mm.
Cat .	1st. 0·0015	164	120	44	2 min.	10 min.
	2nd. 0·0015	140	100	40	3 "	7 "
	3rd. 0·0020	140	78	62	30 sec.	14 "
	4th. 0·01	125	56	76	2 min.	9 "
Cat .	1st. 0·001	180	152	28	65 sec.	5 "
	2nd. 0·0015	167	130	37	70 "	8 "
	3rd. 0·005	155	87	68	120 "	Not recovered.
	4th. 0·010	135	59	76	70 "	2 min.
Dog .	1st. 0·001	171	146	25	120 "	4 "
	2nd. 0·005	158	130	28	30 "	100 sec.
	3rd. 0·01	203	100	103	30 "	Did not again rise above 164 mm.
Rabbit.	1st. 0·001	125	Very irregular tracing with max. pressure 146 mm., and min. 96 mm.			
	2nd. 0·002	121	No change on *average* pressure, but max. raised and min. lowered.			
	3rd. 0·004	130	93	37	120 sec.	3 min.
	4th. 0·005	142	81	61	60 "	5 "
	5th. 0·004	143	75	68	60 "	No further rise above 130 mm.
	6th. 0·005	102	23	79	120 "	No further rise above 66 mm.

This fall of blood-pressure appears under the following conditions:—

1. When any inhibitory action on the heart is excluded by

previous division of both vagi, or administration of a paralysing dose of atropine.

2. When all central nervous influences on the heart are removed by dividing, as far as possible, all the cardiac nerves.
3. When the influence of the vasomotor centres is almost entirely removed by previous section of the spinal cord in the neck.
4. When the central reflexes are paralysed or depressed by a soporific (urethane).

The cause of the primary fall of blood-pressure must, therefore, lie in a direct action of curarine on the peripheral nerves, or on the muscle of the blood-vessels.

In the dog, the primary fall of blood-pressure produced by small but motor-paralysing doses is accompanied, when the vagi are intact, by a distinct quickening of the pulse.

A dog weighing 4·24 kilos. received 0·005 grm. curarine by injection into the jugular vein. Before the injection the average blood-pressure was 170 mm., and the pulse 117 per minute. Two minutes after the injection the average blood-pressure was 159 mm. and the pulse 138 per minute (Plate II. fig. 3).

This agrees with *Traube's* (1) observations on curare. Probably the change is due to a weakening of the normal controlling influence of the vagus.

In the cat, on the contrary, the fall of blood-pressure is accompanied by a slowing of the pulse, and this slowing may be very marked if the fall of pressure is great.

A cat weighing 2·32 kilos. received 0·001 grm. curarine by injection into the jugular vein. Before the injection the average blood-pressure was 176 mm., and the pulse 258 per minute. Two minutes after the injection the average blood-pressure had fallen to 42 mm., and the pulse-rate to 171 per minute. A minute afterwards, on the pressure regaining its former level, the heart rapidly quickened (Pl. II. fig. 1).

In the rabbit there is almost always a very marked slowing of the pulse (Pl. II. figs. 4 and 5).

After this period of primary depression the blood-pressure generally regains and continues at its original level. In rabbits, however, after small paralysing doses of curarine, the pressure very frequently rises, and it may continue even considerably

above the original for from 10 to 60 minutes. (These results are similar to those obtained by *Von Bezold* (2) with curare.)

In dogs and cats the pulse tracing is very regular, and usually free from unexpected variations in pressure whether the dose of curarine be small or large; but, in rabbits, this is usually only obtained after large doses.

A feature of special interest is, that an enormous increase of the reflex excitability of the vasomotor centres occurs in rabbits after the administration of small doses of curarine. In from 1 to 10 minutes a slight stimulation applied to the skin of the paralysed animal—puffing the breath on the fur, shaking the table suddenly, &c.—usually causes an almost instantaneous and often very great rise of blood-pressure. This rise of blood-pressure amounts to an addition of 30–78 mm. in 2 or 3 seconds, and continues on an average from 1 to 5 minutes. Similar changes in pressure occur, without any known stimulation having been applied, when a rabbit is kept paralysed for an hour by the injection of successive small doses of 0·0005–0·001 grm. It is these changes in pressure which in part produce the great irregularities in the tracing when only small doses of curarine have been given.

If the blood-pressure is not already too high, these slight stimulations affect, either directly or indirectly, the cardio-inhibitory centre as well as the vasomotor centres, so that the heart greatly slows as the pressure rises. It is interesting to note, however, that if the blood-pressure reaches a very high level the vagus-pulse disappears and the heart beats very fast, and the waves caused by the artificial respiration almost disappears also; but, whenever the pressure falls somewhat, both reappear.

For example, 10 seconds before a stimulation the pressure was 116 mm., and the pulse 30 in 10 seconds; 10 seconds after the stimulation, with pressure at 138 mm., the pulse was 18 in 10 seconds. As the pressure rose the vagus-pulse became less marked, and was quite set aside when the pressure reached 180 mm. (Pl. II. figs. 6 and 10).

In the following Table examples are given of the effect on the blood-pressure of slight stimuli (blowing on the skin, &c.) in rabbits completely paralysed by the intravenous injection of curarine, and kept alive by artificial respiration. Such effects are not produced in non-curarised rabbits.

Table II.

No. of Experiment.	Amount of Successive Doses of Curarine in Grammes.	*Maximum* Point of Blood-Pressure before Stimulation in mm.	Maximum Point of Pressure after Stimulation in mm.	Maximum Amount of the Rise of Blood-Pressure due to Stimulation in mm.	Time taken after Stimulation before Maximum Point reached.	Time taken after Stimulation before Pressure returned to former *Average* Level.
III.	1st. 0·001	146	174	28	4 sec.	4 min.
	2nd. 0·002	142	186	44	7 ,,	2 ,,
	3rd. 0·004	132	174	42	10 ,,	Continued.
	4th. 0·005	134	144	10	6 ,,	1 min.
	5th. 0·004	100	112	12	6 ,,	20 sec.
	6th. 0·005	66	No further effect.			
IV.	1st. 0·0005	96	172	76	3 ,,	10 min.
	2nd. 0·001	100	158	58	4 ,,	15 ,,
		108	130	22	3 ,,	20 sec.
	3rd. 0·001	80	90	10	5 ,,	4 ,,
		78	126	48	4 ,,	3 min.
V.	1st. 0·0025	98	124	26	5 ,,	Continued.
		100	150	50	6 ,,	10 min.
		92	112	20	3 ,,	5 sec.
		130	No rise.			
	2nd. 0·003	99	109	10	3 ,,	5 sec.
		88	No effect.			
VI.	1st. 0·0008	114	Skin blown upon several times during the first 12 minutes after injection without effect.			
		122	170 (Spontaneous rise apparently.)	48	4 sec.	50 sec.
		132	182	52	14 ,,	60 ,,
VII.	1st. 0·0005	116	158 (Both vagi previously cut.)	42	5 ,,	4 min.
	2nd. 0·0005	98	150 (After stimulating lower end of one of the divided vagi.)	52	20 ,,	5 ,,
		100	160 (After stimulating lower end of one of the divided vagi.)	60	9 ,,	6 ,,
XXXI.	1st. 0·005	98 (Vagi paralysed by atropine.)	158	60	5 ,,	Continued.

The great irregularities of the pulse in the rabbit almost entirely disappear when the vagi are divided in the neck, or when a dose of atropine sufficient to paralyse the vagus is administered. Under these conditions, however, the same marked and sudden rises of blood-pressure follow slight stimulation of the skin.

Plate II. fig. 7 illustrates these points. The piece of tracing *a* shows the curve before the stimulation; *b* shows the rise of pressure and vagus-pulse caused by puffing the breath for a second against the skin; *c* shows the gradual disappearance of the vagus-pulse (and artificial respiratory waves), with very high pressure; *d* shows a regular tracing after both vagi were divided. Plate II. fig. 8 shows that, after the administration of atropine, the same stimulation causes a remarkable rise of blood-pressure, but without any appearance of the vagus-pulse. Plate II. figs. 9 and 10 show, in animals with intact vagi, the strong vagus-pulse which follows slight stimulation of the skin, and accompanies the rise of blood-pressure when that is not excessive.

These reflex vasomotor spasms are prevented—

1. By the administration of a large dose of curarine.
2. By the administration of some soporific (0·5–1·0 grm. urethane).
3. By section of the spinal cord in the neck.

This increase of the reflex excitability of the vasomotor centres in rabbits is a distinct feature of the action of curarine in small doses. It is this symptom which caused *Latschenberger and Deahna* (3) to speak of strychnine containing curares, and which was correctly described by *Grützner and Heidenhain* (4). Only few experiments with small doses of curarine were made on dogs and cats, and in these no evidence of such marked central (vasomotor) action was obtained.

It is known that the inhibitory action of the vagus is suspended by curare. Several milligrammes of curarine (0·005) usually cause this. Slight differences occur in different animals in the amount of resistance offered by the vagus. The vagus of the cat seems most susceptible to the paralysing action, that of the dog less so, while the vagus of the rabbit is most resistant, the dose being calculated on the body-weight.

In the cat, after paralysis of inhibition by curarine, stimulation in the neck of the divided vagus-trunk causes the distinct

accelerator action on the heart, already demonstrated by *Bœhm* (6) with curare.

1. *Cat.*—0·0012 grm. curarine. Pulse before the stimulation, 63 in 20 seconds.
Stimulation of vagus for 30 seconds with induction current (second coil at 65 mm.).
Pulse-rate each 20 seconds during and after stimulation.
I., 63; II., 73; III., 78; IV., 69; V., 68.

2. *Cat.*—0·008 grm. curarine. Pulse before stimulation, 56 in 20 seconds.
Stimulation of vagus for 40 seconds with induction current (second coil at 60 mm.).
Pulse-rate each 20 seconds during and after stimulation.
I., 63; II., 70; III., 69; IV., 63 (Pl. II. fig. 2)

In the cat, dog, and rabbit the vagus nerve, as proved by stimulation, recovers its inhibitory action on the heart before the motor nerves distributed to the voluntary muscles recover.

Even after very large doses of curarine (0·01–0·02 grm.), stimulation of the sympathetic nerve in the neck (in agreement with the observations of *Vulpian* (5) on curare) causes in the rabbit dilatation of the pupil.

The intestines show active movements even after overwhelming doses of curarine. The paralysed abdominal walls are often actively moved about by the contractions of the bowel, defæcation frequently occurring, less frequently urination. Since these intestinal movements are observed although artificial respiration is fully maintained, they are probably due to the action of the alkaloid on the spinal centres, and are analogous to the spasms in the vascular system induced through the vasomotor centres.

After the inhibitory function of the vagus in the rabbit is for the time being paralysed by a dose of curarine which is not excessive, stimulation of the central end of the depressor nerve lowers the blood-pressure distinctly.

Stimulation of the central end of the divided sciatic nerve and suspension of artificial respiration cause, after small and medium doses of curarine, a distinct increase of blood-pressure, if, at the time of stimulation, the blood-pressure is not already at a very high level. When the dose is increased to 0·01–0·03 grm., and more, the pressure falls, and these stimulations no longer produce any effect.

If the spinal cord in the rabbit be divided between the 3rd and 4th cervical vertebræ, and a small paralysing dose of curarine be administered, stimulation of the spinal vasomotor centres by temporary suspension of artificial respiration causes a rise, sometimes very marked, of the blood-pressure. Stimulation of the skin and upper end of the sciatic nerve has no appreciable effect. No spontaneous rises of blood-pressure worthy of note were observed.

In a rabbit of 1·82 kilo., 0·001 grm. curarine was injected into vein. The average pressure was 30 mm. after the cord had been completely divided in the neck. On stopping artificial respiration for 70 seconds the pressure steadily rose to 90 mm., and remained at this height for a considerable time (Pl. II. fig. 12).

When a dog or cat is fully paralysed by a dose of curarine the activity of the vasomotor centres is shown, during the stoppage of artificial respiration, by the Traube-Hering curves (Pl. II. figs. 13 and 14).

Stimulation of the peripheral end of the divided splanchnic nerve gives the usual result, when only small or medium doses of curarine have been administered. As the dose of curarine is increased up to 0·01–0·04 grm. stimulation of the splanchnic gradually loses its effect.

A still larger dose is required before direct electrical stimulation of the spinal cord fails to raise the blood-pressure.

During the period of low blood-tension produced by a maximum dose of curarine the following methods of stimulation fail to produce any alteration in the curve:—

1. Stimulation of the skin.
2. Stimulation of the central end of the divided sciatic nerve.
3. Suspension of artificial respiration until death has occurred.
4. Stimulation of the spinal cord by induction current.

The heart continues to act quite regularly, and seems not to be directly affected by the largest doses of curarine.

It remains to be decided whether the marked lowering of the blood-pressure after large doses of curarine is due to a central or to a peripheral vasomotor paralysis.

Paralysis of the muscle of the blood-vessels may probably be set aside, because, when a solution of chloride of barium is in-

jected, there is an immediate rise of pressure, although previously this could not be effected through stimulation of the nerves and nerve centres.

The initial fall of blood-pressure after small and medium doses seems clearly to be due to a passing paralysing action on the vaso-constrictor nerves. The effect of these injections, however, depends a great deal on the strength of the impulses passing from the vascular centres to the vessels at the moment, just as a paralysis of the motor nerve endings in voluntary muscle is, within certain limits, only relative to the strength of the stimulus applied to the nerve trunk.

For example:—In Experiment XI. the gradual injection of a solution containing 0·001 grm. of curarine into the jugular vein of a rabbit produced a steady fall of pressure from 130 to 120 mm. At this point, while the pressure was still falling and the animal was quite paralysed, a puff of air was sharply blown for a moment on the fur covering the abdomen, and the pressure almost instantly rose to 172 mm. Meanwhile the injection was steadily continued, but an additional 0·004 grm. of curarine had no effect in lowering the pressure from this high level. Had no stimulation been applied during the injection, and reflex tetanus of the vessels not therefore induced, the pressure would have probably continued to fall.

When the vasomotor centres are in an unexcited condition their tonic action on the vessels seems to be overcome by the paralysing action of the curarine on the vaso-constrictor nerves as it passes along in the blood-stream. As the poison reaches the capillaries, tissues, and veins, comparatively unpoisoned blood flows through the arteries, which contract again under the normal action of the nerve centres. Not unlikely also, once it has passed through the arteries, the poison is only slowly given up by those parts on which it acts most powerfully—the nerve-end apparatus in the voluntary muscles. Unless the curarine is actually in some quantity in the vessels the nerve centres can overcome or greatly reduce the peripheral paralysis, if excited in any way to exert an extra influence.

For example:—In a tracing taken from a cat, and referred to already, the administration of only 0·001 grm. caused a fall of pressure from 176 to 42 mm. in $2\frac{3}{4}$ minutes. A few seconds later the pressure began suddenly to rise and in 8 seconds it reached 140 mm., and soon regained its original level, showing that the vasomotor centres, stimulated in this case probably by the absence of oxygen-

ated blood, were quite capable of immediately overcoming the peripheral paralysis due to this dose.

With larger doses the peripheral paralysis is more marked and persistent.

For example:—In a rabbit the injection of 0·0015 grm. curarine lowered the pressure from 106 to 90 mm. At this point the spinal cord was directly stimulated and the pressure rapidly rose to 190 mm. On quickly injecting 0·0085 grm. the pressure fell to 97 mm., and a minute later 0·015 grm. was injected and the pressure fell to 50 mm. No rise of pressure now followed reflex and direct stimulation of the vasomotor centres. On continuing at intervals the direct stimulation, and gradually increasing the strength of the current (second coil from 100 to 60 mm.), the pressure began slowly to rise, and after several minutes reached 170 mm. and maintained this level for a considerable time without further stimulation.

These experiments were repeated with various modifications, and it was found that—

1. The great lowering of blood-pressure caused by large doses of curarine was not at first affected by either reflex or direct stimulation of the vasomotor centres.
2. After a time, a high pressure could be maintained by the nerve centres alone, the spontaneous recovery of the pressure agreeing with the increased effect of reflex as well as direct stimulation of the vasomotor centres; and this seemed to indicate that the paralysis was a passing peripheral one.

This conclusion was borne out by the results obtained on stimulating the splanchnic nerve. Four experiments were made. In two cases the nerve was exposed in the thorax, and in other two in the abdomen between the diaphragm and the distribution of the nerve above the kidney.

Before the administration of curarine stimulation of the divided nerve caused a rather sharp rise of pressure of 20–30 mm. After the injection of 0·02 grm. curarine stimulation with the same strength of current had almost no effect. Minute after minute the stimulation gained in effect, the brief rise after five successive stimulations being 5, 7, 10, 15, and 20 mm. The next injection of curarine lowered the pressure as before, and again stimulation of the splanchnic gradually regained effect.

At the same time that the stimulation of the nerve became

effectual, the general level of the blood-pressure began spontaneously to rise, a proof that the nerve centres were not paralysed, but could effect nothing until the vaso-constrictor nerves recovered somewhat. While strong electrical stimulation might of course in any experiment effect what the physiological stimulus of the living centres could not, it is, on the other hand, quite clear, that when electrical stimulation failed to overcome the peripheral paralysis, the nerve centres could not be expected to succeed, even if they were in a state of the highest activity. There is every reason to believe that, in experiments of moderate duration where large doses of curarine are employed, the vasomotor centres continue throughout to act with great vigour, and that the fall of blood-pressure is solely due to an action on the vasomotor nerves. The vasomotor nerves in the rabbit are fully paralysed, for the time at least, by a dose of curarine which is 100 to 300 times greater than that which paralyses the motor nerves.

Polyuria and glycosuria have been observed in curarised animals by *Bernard* (13), *Eckhard* (14), and others.

These symptoms occurred in the blood-pressure experiments recorded here, after the administration of small and medium doses of curarine.

From a clinical point of view (ague, paroxysmal hæmoglobinuria, intermittent albuminuria due to chills, &c.), it was especially interesting to find that albumen, and frequently also blood pigment and blood in considerable quantity, could be readily (within an hour) caused to appear in the urine of a perfectly healthy rabbit paralysed by a small dose of curarine, if simply severe vasomotor spasms were induced, as described, by slight stimulation (blowing the breath) of the skin. The characters of the urine, and the conditions under which these symptoms occurred, have been examined at some length, but the observations are not yet complete enough, and have not therefore been given in detail.

PART IV.

Notes on the Action of Curine.

In 1886 *Bœhm*[1] separated from certain curares, in addition to the alkaloid curarine, an alkaloid which he has named curine.

Curine, even in large doses, has no apparent action on motor nerves; but, as will be seen from the following examples of experiments, it acts on the heart in both frogs and rabbits:—

Frog. October 1887. *Experiment with No.* 1 *Curine (from Tube-Curare). Heart exposed. Rate,* 34–37 *per minute; strong.*

3 h. 50 m.	Injection of 0·004 grm. subcutaneously.
3 „ 54 „	Heart 40 per minute.
4 „ 2 „	Same injection repeated.
4 „ 7 „	Part of the ventricle, near the aortic bulb, shows aneurism-like dilatation during systole.
4 „ 14 „	Right and left side of ventricle do not contract at same time.
4 „ 17 „	Ventricle occasionally stops. Systole quite irregular and peristaltic.
4 „ 21 „	Auricle, 44 } Ventricle, 21 } per min., the ventricular contraction being more regular.
4 „ 42 „	Auricle, 41 } Ventricle, 20 } The upper half of the ventricle first contracts while the apex is bulged out.
	On the following day—
10 A.M.	Auricle, 24 } Ventricle, 12 } Ventricle peristaltic.

Frog. February 1888. *Experiment with Curine No.* 2 (*from very active Pot-Curare*).

4 h. 20 m.	Heart exposed. Systole strong and regular. Rate 20 per min. Injection of 0·01 grm. curine subcutaneously.
4 „ 35 „	Rate 22 per min.
4 „ 40 „	„ 24 „ Injection repeated.
4 „ 50 „	„ 28 „ Injection of 0·017 grm.
5 „ 25 „	Diastole very short. Systole peristaltic and never complete.
5 „ 30 „	Heart stopped in diastole. Occasionally slight movement of ventricle.
5 „ 40 „	Atropine without action on the heart. Respiration, reflexes, and motor power still good.
	On the following day the ventricle in rigor mortis.

[1] *Loc. cit.*, vol. xxiv. part i. p. 406.

Frog. February 1888. *Experiment with Curine No.* 2.

10 h. 0 m. A.M.	Untied intact frog weighing 50 grms., received 0·01 grm. curine in 0·5 c.c. water subcutaneously.
12 „ 30 „ P.M.	The frog's movements have gradually become weaker, and when placed on its back it cannot turn over.
	On exposing the heart it was found to be much dilated, the ventricle contracting at 8 and the auricles at 9 per min.
1 „ 10 „ „	Auricle, 8; Ventricle, 4 } per min.
1 „ 20 „ „	Auricle, 8; Ventricle, 2 } per min.
4 „ 0 „ „	Ventricle found stopped in systole. Muscles re-respond to stimulation of sciatic nerve.

Frog. February 1888. *Experiment with Curine No.* 2.

4 h. 20 m. P.M.	Heart exposed. Rate 36 per min. 0·005 grm. curine in 0·25 c.c. water subcutaneously.
5 „ 10 „ „	Rate 38 per min. Beginning of peristalsis.
5 „ 45 „ „	Strong peristalsis, the ventricle not emptying.
6 „ 20 „ „	Auricle, 20; Ventricle, 10 } per min.

Other such experiments were in agreement, showing that curine caused in the frog an interference with the heart's activity of a similar character to that caused by veratrine or the digitalis-group of poisons.

In rabbits the subcutaneous administration of curine (0·2 grm. of sulphate in nearly 10 c.c. water in 3 doses during 1 hour) was not followed by any very marked symptom, but, when similar doses were injected into a vein in blood-pressure experiments a distinct action was observed.

In the first experiment the heart immediately stopped while 0·24 grm. was being injected into the jugular vein.

In the second experiment 0·08 grm. in 4 c.c. water was injected into the saphenous vein. The blood-pressure almost at once fell to zero and did not recover. The heart continued contracting for 14 minutes in a feeble, irregular manner and then stopped.

In the third experiment smaller doses (see Table below) were employed. A distinct fall of pressure with slowing of the pulse and increased amplitude of the contractions followed each injection. The blood-pressure soon recovered its original level, but the slowing of the pulse and the increased amplitude of the waves persisted a considerable time. In this experiment the injections followed each other

rapidly, but later experiments show that the slow pulse may be accompanied by an increase of blood-pressure, when the doses are given after longer intervals.

EXPERIMENT III., *August* 1887.—*Rabbit*, 1·85 *Kilo.*

Dose in Grammes.	Average Blood-Pressure before Injection in mm.	Lowest Level of Pressure after Injection in mm.	Time taken before Maximum Depression reached.	Time before Recovery of Pressure.	Pulse for 20 Seconds	
					Before Injection.	After Injection.
1st. 0·020	87	67	50 sec.	3 min.	77	67
2nd. 0·020	86	53	35 ,,	1½ ,,	71	58
3rd. 0·04	86	36	70 ,,	5 ,,	61	37
4th. 0·06	85	32	60 ,,	8 ,,	55	30
5th. 0·08	87	29	120 ,,	9 ,,	65	30
(Vagi	cut.)					
6th. 0·01	79	48	120 ,,	6 ,,	58	46

In Experiment V. both vagi were divided in the neck and artificial respiration was maintained. On slowly injecting 0·06 grm. curine in 3 c.c. water into the saphenous vein the heart stopped, but, on pressing the thorax several times, the heart resumed beating. The blood-pressure gradually rose from the original level of 100 mm. to 150 mm., with a slow powerful pulse of 55 in 20 seconds. The stimulation of the lower end of the vagus had its usual action.

In Experiment VI. atropine was first administered, and the inhibitory action of the vagi fully suspended. On injecting 0·02 grm. curine the pulse slowed distinctly. Fifteen minutes after the first injection a second injection of 0·028 grm. was given, and the pressure meanwhile steadily rose from the original level of 104 mm. to 146 mm., and the pulse slowed from 279 to 159 per minute, the amplitude of the waves being much increased.

A third injection of 0·03 grm. caused complete stoppage of the heart. On opening the thorax the auricles were found to be contracting, and they continued to do so for about 15 minutes. The right ventricle was dilated; the left contained a small quantity of blood. Occasionally quivering movements of the ventricles occurred.

Vulpian[1] speaks of cases where curare paralysed the heart in frogs, *the auricles beating twice as fast as the ventricle*, which was finally arrested through the failure of the cardio-motor ganglia. This occurred several times in rabbits and once in a dog. Vulpian could not understand this, as curare usually did not seem to act on the heart at all, except through its action on the vagus. *Couty and De Lacerda*,[2] *Von Bezold*,[3] and *Paul Bert*[3]

[1] *Loc. cit.*, part i. (3), pp. 360–2.
[2] *Ibid.*, (35), p. 698.
[3] *Ibid.*, quoted (35), p. 698.

also note that the quick injection of curare into a vein may lessen, or even arrest, the movements of the heart.

I have never observed any sign of cardiac paralysis in rabbits on administering curarine, even when enormous doses were rapidly injected into the jugular vein. On two occasions the heart stopped 20 minutes or so after the administration of *small* doses of curarine, but this coincided with a sudden and very marked rise of blood-tension; and the cardiac paralysis was here apparently due to overstrain caused by the reflex tetanus of the vessels.

Curine may be present in different curares in unknown proportions. In experiments where small paralysing doses of curare are employed, the action of curine, if present, may not be observed, and could, perhaps, be neglected, since the active dose of curarine is so much smaller. In precise experiments on mammals, where larger doses of the crude arrow-poison are employed, the possible presence of curine is a fallacy which should not be overlooked.

No further experiments were made at this time, as the chemical examination of the specimens obtained by Bœhm from different curares was not concluded.

It is not yet known from what sources in South America the arrow-poisons containing curine are derived.

There seems to be no doubt that several of the strychnos barks of South America yield cardiac poisons, while a number of others yield curarine-acting bodies. Couty and De Lacerda[1] state that the extract obtained from the bark of the *Strychnos Gardnerii* of Brazil causes, in warm-blooded animals, disorder of the heart's action, fall of blood-pressure, and secondary arrest of central excitability and respiration, without any apparent action on motor nerves. These authors also state that on boiling the extract from *Strychnos triplinervia*, and on boiling some curares of unknown composition, the original weak paralysing action on motor nerves was destroyed, and replaced by a paralysing action on the heart. Other curare-sorts were not altered in pharmacological action by prolonged boiling with water.

Among several specimens of South American strychnos plants which I examined in Edinburgh in the winter of 1888–9 was

[1] *Ibid.*, p. 1035.

one which had been sent to the Royal Gardens, Kew, from Antioquia, in New Granada, as a specimen of *Strychnos toxifera*, and of which Mr Jackson kindly sent me a small part of a young stem. On examination, I found that it did not agree with the descriptions we possess of *Strychnos toxifera*, but it seemed exactly to correspond with the description by *Planchon*[1] of the *Strychnos Gubleri*, which was brought from Venezuela by M. Thirion in 1867. This strychnos is reputed to be the basis of the curare of the Upper Orinoco district, but is not identical, Planchon thinks, with the *bejuco de Mavacoure* of *Humboldt and Bonpland*, from which certainly curare was prepared. I do not know of any experimental evidence which shows that *Strychnos Gubleri* has an active motor-paralysing action. That it enters into the composition of the particular curare referred to is no doubt the case; but, meantime, its claims to be the basis seems only to rest on the insufficient ground of native report, and the fact that it is a strychnos plant.

The watery extract obtained from the small available quantity of the bark of this New Granada strychnos plant had no curare-like action. In brainless frogs paralysis of reflexes occurred after several hours, but this was found to be due to an interference with the circulation, the ventricle after a time acting in a feeble peristaltic manner, and, becoming paralysed (large doses could not be tried) in diastole.

In this direction, it is interesting to remember that *Hammond and Weir Mitchell*[2] obtained from New Granada, some thirty years ago, two arrow-poisons, named corroval and vao, which they found produced paralysis of the heart.

The South American arrow-poisons at present definitely known to us by experiment consist, therefore, either of curarine or of curine-acting substances, or of mixtures of these.

[1] *Ibid.*, part i. (36), p. 492.
[2] *Amer. Jour. Med. Sci.*, vol. xxxviii., Philadelphia, 1859.

LITERATURE.

1. *Medicin. Centralbl.*, Nos. 4 and 5, 1863.
2. *Untersuch. über die Innerv. des Herzens*, Bd. ii. s. 312, 1863.
3. *Pflüger's Arch.*, Bd. xii. s. 159, 1876.
4. *Ibid.*, Bd. xvi. s. 54, 1878.
5. *Leçons sur les subst. toxiques*, pp. 295, 301, 320, 326, Paris, 1882.
6. *Archives f. exp. Path. u. Pharmakol.*, Bd. iv., 1875.
7. *Jour. of Physiol.*, vol. i. p. 273, 1878.
8. *Pflüger's Archiv*, Bd. xv. s. 599, 1877.
9. *Archives f. exp. Path. u. Pharmakol.*, Bd. xxii. s. 77, 1887.
10. *Jour. of Physiol.*, vol. iv. p. 461, 1883.
11. *Ibid.*, 1878–9, p. 437.
12. *Compt. Rend.*, t. 89, p. 725, 1879.
13. *Leçons sur les subst. tox. et médic.*, p. 342, 1857.
14. *Beiträge*, Bd. vii. p. 166.

EXPLANATION OF PLATE II.[1]

Fig. 1. Blood-pressure trace. Cat. Time-mark on abscissa = 2 seconds. *a*, normal curve before injection of curarine; average pressure, 167 mm.; pulse, 86 in 20 seconds. *b*, curve 50 seconds after injection of 0·001 grm. curarine into jugular vein; beginning of artificial respiration; pulse, 68 in 20 seconds. *c*, curve 2 minutes after injection; pulse, 57 in 20 seconds. *d*, curve 3 minutes after injection; sudden recovery of blood-pressure.

Fig. 2. Blood-pressure trace. Rabbit. Time-mark as in fig. 1. Fall of blood-pressure on injecting into vein 0·005 grm. curarine.

Fig. 3. Blood-pressure trace. Dog, weighing 4·24 kilos. Time-mark = 1 second. *Ordinate reduced.* *a*, curve 2 minutes before the injection of 0·005 grm. curarine; average pressure, 170 mm.; pulse, 39 in 20 seconds. *b*, curve 2 minutes after the injection; average pressure, 159 mm.; pulse, 46 in 20 seconds.

Fig. 4. Blood-pressure trace. Rabbit. Time-mark = 2 seconds. Ordinate reduced. *a*, curve 20 seconds before the injection of 0·001 grm. curarine; pulse, 76 in 20 seconds. *b*, curve 20 seconds after the injection; pulse, 34 in 20 seconds.

Fig. 5. Blood-pressure trace. Rabbit. Time-mark = 2 seconds. Ordinate reduced. From α to β slow injection of 0·0025 grm. curarine. At γ beginning of artificial respiration. At δ skin slightly touched.

Fig. 6. Blood-pressure trace. Rabbit. Time-mark = 2 seconds. Ordinate reduced. At α the table shaken.

[1] In all cases after the administration of curarine motor paralysis was complete and artificial respiration was maintained. Those phenomena which depend on the reflex excitability of the vasomotor centres (figs. 6, 7, 8, 9, &c.) are of course absent, if the centres are, at the time of the tracing, depressed by any anæsthetic or hypnotic.

Fig. 7. Blood-pressure trace. Rabbit. Time-mark = 1 second. Ordinate reduced. 0·002 grm. curarine. *a*, *b*, *c*, *d* referred to in text.

Fig. 8. Blood-pressure trace. Rabbit. 0·005 grm. curarine after administration of atropine. Time-mark = 1 second. At *a* slight stimulation by a puff of air on skin.

Fig. 9. Blood-pressure trace. Rabbit. Time-mark = 1 second. At *a* slight stimulation by a puff of air on skin after 0·001 grm. curarine.

Fig. 10. As in fig. 9.

Fig. 11. Blood-pressure trace. Cat. Time-mark = 2 seconds. Ordinate reduced as in figs. 8, 9, 10, &c. From *a* to β (40 seconds) stimulation of right vagus nerve, with induction current 60 mm. 0·008 grm. curarine.

Fig. 12. Blood-pressure trace. Rabbit. Time-mark = 2 seconds. Original ordinate. Spinal cord divided previously. 0·001 grm. curarine. From *a* to β (70 seconds) artificial respiration suspended.

Fig. 13. Blood-pressure trace. Dog. Time-mark = 1 second. Ordinate reduced. 0·016 grm. curarine. From *a* to β suspension of artificial respiration. Traube-Hering waves.

Fig. 14. Blood-pressure trace. Cat. Time-mark = 2 seconds. Ordinate reduced. 0·007 grm. curarine. From *a* to β suspension of artificial respiration.

CONTRIBUTIONS TO THE COMPARATIVE OSTEOLOGY OF ARCTIC AND SUB-ARCTIC WATER-BIRDS. PART VIII. By R. W. SHUFELDT, M.D., C.M.Z.S., &c.

(*Continued from* vol. xxiv. (N.S. vol. iv.), page 566.)

Of the Appendicular Skeleton of the Laridæ and Stercorariidæ.

UNFORTUNATELY the most of the skeleton of the pinion of my specimen of *S. parasiticus* has been lost. In other specimens of the same group the entire limbs are missing, and no doubt the birds were originally prepared as skins, and only such parts as the taxidermist usually throws away were saved.

The head of carpo-metacarpus in a Jaeger, however, rather leads me to believe that these parts are a good deal like the hand skeleton in the Gulls; at the same time there is no little room for doubt in the matter, as the bone of the brachium presents several differences in the two families.

The skeleton of the pectoral extremity in *Rissa* is shown in fig. 9 of Part VII. This presents a very good illustration of the general form of these bones and their relations as to comparative lengths and calibres in a Gull, but there are yet many interesting details that cannot be very well displayed in such a drawing. Of all the specimens of Gulls before me, no one of them exhibits these latter more strongly marked than does *L. glaucus*. So that, for the purpose of describing this limb, we will choose this bird, and note the differences found in the others as we proceed.

With the bones of this limb articulated as in life, and the member in a position of rest alongside the trunk, we notice that the antibrachial skeleton projects well beyond the humerus, and further, that the skeleton of the pinion is very nearly as long as that of the fore-arm.

I find no sesamoids at the elbow, and there are no claws or extra joints in the hand of this Gull; in short, the limb is

reduced to the minimum number of bones, as seen among the vast majority of existing birds.

The *humerus* is large and well proportioned, as are the other bones of this extremity.

At the palmar aspect of its proximal extremity we find a large subcircular convex surface occupying the most of the middle and lower areas. This is separated from the articular head of the bone, and the proximal moiety of the radial crest by a continuous and deep trench. The radial crest is a conspicuous and triangular plate that extends but a short distance down the shaft. Its surfaces look directly upwards and downwards, and its apex points to the palmar side.

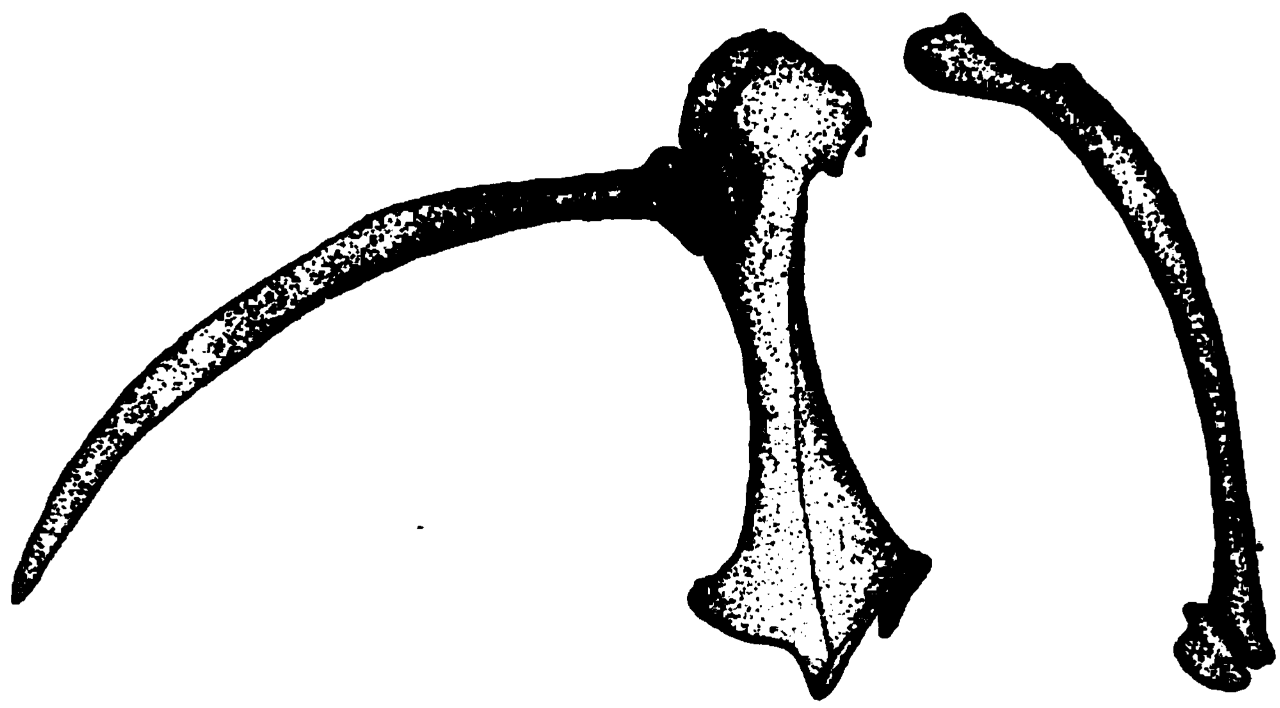


Fig. 1.—Outer aspect of shoulder girdle of *Stercorarius pomarinus*; right side; clavicle detached. (Specimen 12,605, Smithsonian Collection). Life size.

A very extensive and deep concavity occupies the entire anconal aspect of this proximal end of the humerus. This is divided into two equal parts by a vertical plate of bone. The superior division is arched over by the curling articular head; the inferior division, and more projecting one, represents the pneumatic fossa, and is arched over by the ulnar crest. The humerus, as in the case with all the other bones of this limb, is non-pneumatic, and this fossa has its walls beyond the shaft proper, and all very thin. An ordinary light is readily transmitted through them when the bone is held up to it.

Equally striking are the characters at the distal extremity of this humerus of the Burgomaster Gull; for here we not only find the articular trochleæ unusually prominent, but immediately

beyond them the expanded portion of the palmar aspect of the shaft is excavated to the last degree succeeding complete perforation. This is not so well seen in other *Laridæ*. Another very marked feature is the notable ecto-condyloid process that stands out from the radial border of the shaft. This is a character of both these families, as it is of many other far or nearer related groups. Tendinal grooves mark the anconal side of this extremity.

The humeral shaft itself is nearly devoid of its usual sigmoid curves, being quite straight and subcylindrical in form. A nutrient foramen is observed to pierce it at the usual site.

These characters of the humerus are seen to vary among the other genera of Gulls, but they are invariably present, though they may differ in the degree to which they are developed. Age also has its influence, as I find the pit described for the distal extremity not nearly so deep in a young *L. glaucus* as in the adult one referred to above.

Jaegers have an entirely different humerus from the Gulls.

The bone is completely pneumatic, and, although the palmar aspect of the proximal end resembles in most particulars the bone described for the *Laridæ*, the opposite side has no excavation whatever below the articular head; the ulnar crest has the form most commonly seen in birds, and overarches an elliptical and deep pneumatic fossa.

It will be observed in fig. 3 that the sigmoid curve of the shaft is fairly well developed, while the ecto-condyloid process is prominent at the distal end of it. The excavation beyond the trochleæ at this extremity is present, but not sufficiently deep to attract particular attention.

The proximal articulation of *ulna* and *radius* has nothing peculiar about it. The olecranon of ulna is but feebly produced beyond the shaft, and not at all beyond the articular cup for the ulnar tubercle of humerus. The shaft itself of this bone is nearly cylindrical in form, and shows a row of about eighteen prominent papillæ for the quill-butts of the secondary feathers of the wing.

Distally, fully the anterior moieties of the shafts of these bones of the antibrachium are in contact with each other when the limb is in a natural position. The proximal and remaining

parts inclose a spindleform interosseous space, the shafts of the bones being gently concave towards each other.

Nothing of importance attaches to the distal articulation of these antibrachial segments that need detain us, nor does the carpal joint depart in any way from the composition it has in the vast majority of the class. The two free ossicles entering into it have the form usually seen, and support the same number of articular facets.

FIG. 2.—Pelvis of *Stercorarius pomarinus*, viewed from above. (Specimen 12,605, Smithsonian Collection.) Life size, by the author.

Carpo-metacarpus is longer than half the radius; its main shaft is perfectly straight, and rather inclined to be a little flattened from before backwards. Middle metacarpus is rod-like for its lower half, transversely expanded above, slightly convex towards the index metacarpal, and spans it from one

extremity to the other, supporting no peculiar processes or elevations in any part of its source.

The anterior aspect of the distal end of index metacarpal, as well as the corresponding point on its proximal phalanx, each develop a prominent process for the guidance of tendons.

This feature, we remember, was present in the true Auks. Pollex metacarpal is short, and anchylosed at an angle with the main shaft of the bone. The phalanx it supports is only half as long as the distal one of index; in form it is compressed from side to side for its lower two-thirds, being subtrihedral above.

FIG. 3.—Radial aspect of left humerus, *Stercorarius parasiticus.* (Specimen 13,648, Smithsonian Collection.) Life size, by the author.

One of them, if not the most striking feature in the skeleton of the pinion of a Gull, is the shape assumed by the proximal phalanx of index digit. This is not due to its general form and size, as they agree in proportion with the other elements of the pinion, but to the fact that its expanded portion behind is invariably subdivided into two partitions, an upper and a distal one, by a ridge of bone, which connects the main shaft of the joint and its posterior thickened margin. The areas thus enclosed are entirely deficient in bone, and, of a consequence, we find these free rod-like boundaries surrounding two large vacuities of nearly equal size.

This condition is well shown in our figure of the skeleton of the arm of *Rissa* referred to above.

The distal phalanx of index is very long, and flattened from before backwards. Posteriorly it is excavated above, and shows a peculiar enlargement below on the same aspect. Agreeing with the phalanx of pollex, this joint never bears a claw in the Gulls, as we found in the Parrot Auks and others.

I am aware that Nitzsch has placed the *Gaviæ* in his list of birds in which this claw is said to be found, but in the case of *L. glaucus* and other Gulls he is certainly in error. My

material permits me to state this quite positively, as in numbers of the skeletons both the skin and quills are still attached to the extremities of these very phalanges, and not even a rudiment of a claw is to be found in any of them.

The small joint of middle metacarpal is less than half as long as the broad joint of index, which lies next to it. It has its most usual form as seen in birds, being perhaps rather more compressed from side to side than is common. Among the Jaegers the bones of the antibrachium seem to agree in all essential particulars with the same segments we have just described for the Gulls. As already explained, I am unable to say anything for lack of material about the skeletal parts of the pinion in the *Stercorariidæ*.

Of the Pelvic Limb.—This extremity in the *Laridæ* is a non-pneumatic one, none of the bones showing any foramina at the usual sites where these apertures exist, for the purpose of admitting air to their cavities. The femur in the *Stercorariidæ* may prove to be an exception to this rule, as the bone in *S. parasiticus* has all the appearance of a pneumatic one, in the skeleton at my hand, but I have been unable to detect the presence of the foramina in it. The leg bones and bones of the feet in the Jaegers are, however, like what we find in the Gulls in this respect.

The *femur* in *L. glaucus* has the articular surface at its summit directly continuous with that of the head of the bone, robbing the latter of its usual globular form. This head is sessile and at right angles with the shaft, that is, the line perpendicular to its base is. Above, it shows the usual excavation for the round ligament, a pretty extensive concavity in the Gulls.

The trochanterian ridge is very prominent, both at the summit and side of the shaft. It is well elevated above the surrounding surfaces, and is very broad at its outer aspect.

Below this part, the shaft, which is nearly straight, soon becomes cylindrical in form, with its muscular lines barely perceptible on its otherwise smooth surface.

The external condyle is the larger of the two, and deeply cleft behind for the fibular head.

Both the rotular channel and the popliteal depression are deep and capacious.

In general points the femur of the *Stercorariidæ* essentially agrees with the same bone just described for the Gulls, with the exception of its suspected pneumaticity. Gulls all have an exceedingly small and luniform *patella*, with its long axis transverse to the line of the tendon, and situated in life at a considerable distance above the cnemial process of tibio-tarsus.

Stercorarius, on the contrary, has a long patella that in life reaches down to the cnemial process, and shows across its anterior face an oblique groove for the ambiens muscle. The sesamoid in this Jaegar (*S. parasiticus*) looks as though it might have developed from two centres of ossification.

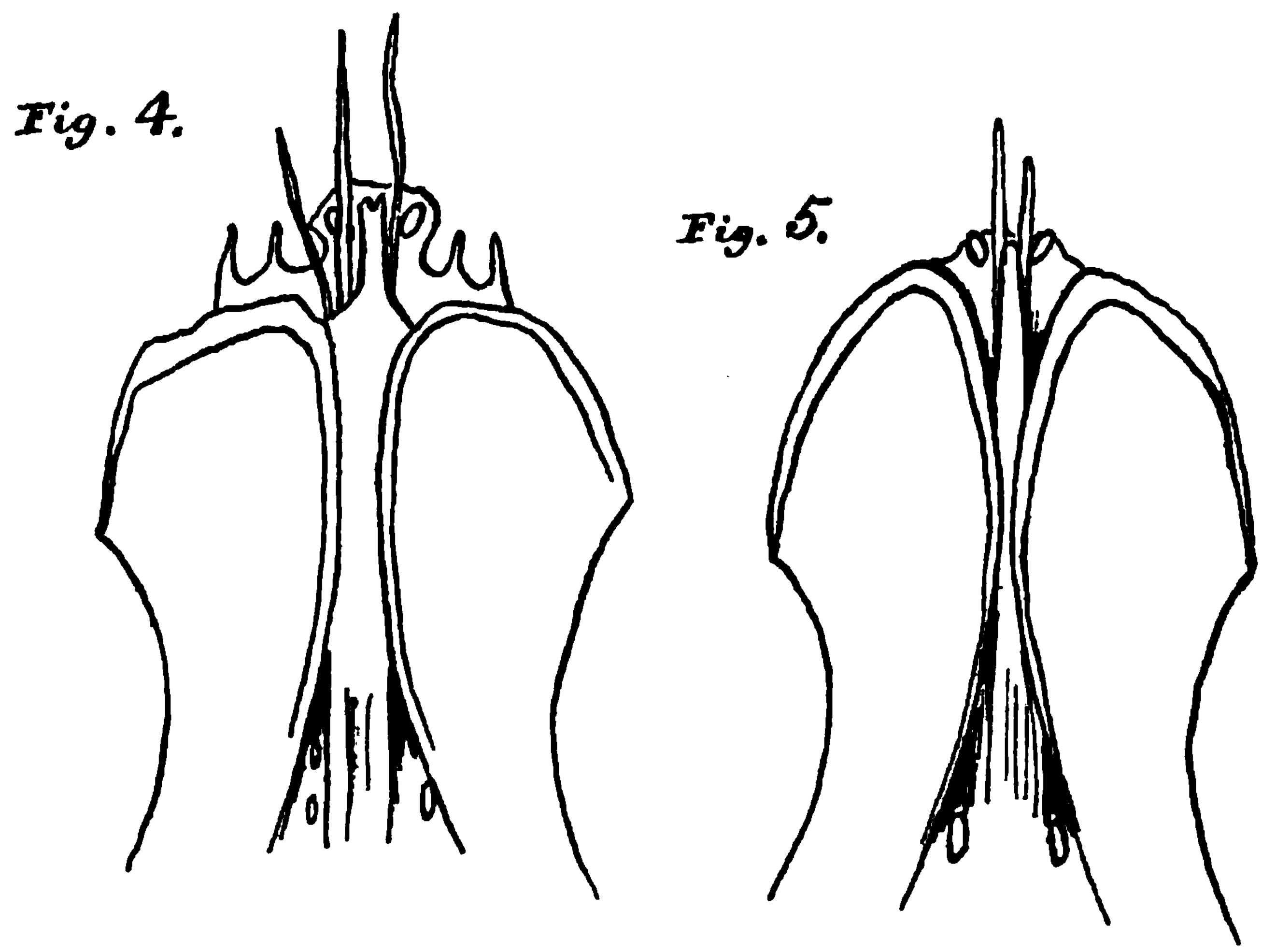


FIG. 4.—Outline of anterior portion of pelvis of *Larus glaucus*, adult, viewed from above. (Specimen 16,988, Smithsonian Collection.)
FIG. 5.—Outline of anterior portion of pelvis of *Larus glaucus*, young (bird of the year). Same view. (Specimen 16,777, Smithsonian Collection.) Both life size; by the author.

The summit of the *tibia* projects beyond the shaft all around, the latter sloping gradually up to it, except behind, where the union is quite abrupt. The cnemial process is reared above the articular surface for the femoral condyles. The cnemial ridges are very prominent, and merge directly into the anterior surface of the shaft above the superior termination of the fibular ridge at the side, or rather the imaginary horizontal line drawn through that point. With the anterior surface of the bone

facing you, the two plane surfaces of the ectocnemial ridge look directly forwards and backwards.

The procnemial ridge is at right angles to this, is the larger of the two, and extends somewhat lower down upon the shaft.

The inferior margins of these ridges are thin and sharp, while the superior ones are thickened, convex, and continuous at the apex of the process.

As a rule, the anterior surface of the tibial shaft is flattened, more particularly its lower half; while for its entire length the lateral and posterior surfaces form one continuous convex remainder. Among all the Gulls the tibial shaft is long and straight, and for the comparative size of the birds rather slender. Figures of these bones will be given in a plate in Part IX., which follows. Its distal extremity is much expanded in a transverse direction, the condyles in front protruding, and being separated by a wide intercondyloid fossa. Above them we see the usual osseous bridge over the tendinal groove, here also rather wide in proportion. Behind, the condyles approach each other, are less prominent, and are sharp ridges, instead of being thickened and convex, as they are in front, and continued for a short distance upon the lower end of the bone.

Both *Laridæ* and *Stercorariidæ* possess the *fibula* as a free bone; its lower and filamentoid extremity being opposite the middle of the tibial shaft, but not anchylosed with it.

Above, it articulates in the usual way by ligamentous attachment to the lateral fibular ridge, and by like means in the recess behind the ectocnemial wing of the cnemial process of the tibia. Generally, in both these families the *tarso-metatarsus* is considerably longer than half the length of the tibia. *Rissa* constitutes a notable exception to this rule, as it has the bone equal in length to just half the tibia, and in size proportionately stouter than in the other forms. As a rule, the shaft of this bone is perfectly straight, more or less flattened upon all four of its surfaces, and exhibits a shallow longitudinal groove in front for the better retention of the extensor tendons.

It is more deeply excavated just below its head anteriorly, where we also observe the two foramina which pierce the bone from before backwards.

The hypotarsus is tuberous, rather inclined to extend down

the shaft, and shows one median and deep longitudinal groove, with two smaller ones to its outer aspect. I have never found it vertically perforated among these birds, as we see it in others.

The trochleæ of the distal extremity are generally large, and marked by the usual median grooves. A deep cleft separates the middle and outer one, while the inner one, which at the same time is the most posterior and highest of all, is adherent to the side of the shaft at the base of the middle one.

A large arterial foramen pierces the bone at the usual point in the continuation of the groove between outer and middle trochleæ.

The three anterior podal digits have their joints arranged upon the more usual plan, as seen in the class generally, *i.e.*, 3, 4, 5 phalanges to second, third, and fourth toes. Their proportionate lengths and calibre may vary somewhat among the different genera, but beyond that they exhibit nothing in their form or composition that departs to any marked extent from the common type of these segments.

Not so, however, with the hallux, for it presents quite a number of conditions in several of the forms of Gulls and Jaegers. In *Rissa*, for instance, the accessory metatarsal is an exceedingly small, though free, nodule of bone, suspended in the usual way at the edge of the shaft by ligament. It supports the rudimentary basal joint of hallux that lacks the usual ungual phalanx. The articulation between the two is a perfect one, and the podotheca takes this rudimentary structure into consideration, and envelops it in a separate sheath, as it does in the case with the other toes.

L. glaucus has its hallux very much reduced also, but all the elements are present. The *Stercorariidæ* are better off in this respect, and in them the hind toe is nearly of a proportionate size with the others. Bonaparte's Gull and the Common Ringbill hold about a middle place with regard to the extent of this hallucial development.

Remarks upon a Skull of Rynchops nigra.

The only skull of this bird is unfortunately an imperfect one, it evidently having been first made into a skin and eventually skeletonised. The occipital area has been cut away, and in my

drawing this has been indicated by lighter stippling, the restoration being made by the assistance of a Gull's skull. What there is of the specimen, however, is in good condition, clean, and will answer the purposes of description very well indeed. Dr Coues, who has examined the skeleton, says it agrees in nearly all particulars with the skeleton of a typical Tern.

Twenty years ago I collected a number of these Skimmers in the Bahama Islands, but have no skeletons of them by me now.

In *Rynchops* the cranio-facial hinge is of the most perfect character, and is formed simply of a thin plate of bone extending from one side to the other. Below, it is not encroached upon by the jutting ethmoid, while superiorly the frontals are cut transversely square across as soon as they reach it, the premaxillary being served in precisely a similar way. This leaves a deep transverse interval between the bones mentioned, and their rounded sides form the walls of this unique cranio-facial channel (fig. 6).

Beyond this the premaxillary soon contracts, and the gently convex culmen has a sharpened edge all the way to the pointed mandibular apex.

The inferior edge of this peculiarly compressed bill is longitudinally grooved in the median line for its entire length. The sides of the superior mandible are convex from above downwards, uniformly smooth, and very gently concave lengthwise.

Each external narial aperture is rather long and subelliptical. It opens through its posterior arc into the nasal slit, which is directed upwards and backwards.

A *nasal* is very long, and articulated in the most extraordinary manner. Its upper end is flattened from above downwards, is anchylosed with the anterior surface of the corresponding lacrymal; as it descends the shaft it is twisted at right angles to this end, being separated from the bulging frontals, the edge of the cranio-facial hinge, and the premaxillary by a very narrow slit. Its distal extremity is flattened to agree with the upper one, and fuses with the usual bones below. This arrangement of the nasal is auxiliary to the cranio-facial hinge. The descending process of the *lacrymal* is bent inwards to meet the small ethmoidal wing and thoroughly anchylosed therewith, while above this bone merges indistinguishably with the frontal.

The sphenotic process is a prominent hook standing directly out from the side of the skull, the crotaphyte fossa forming its posterior surface and the nasal pit the anterior. This latter

Fig. 7.

Fig. 6.—Right lateral view of the skull of *Rynchops niger*; the dotted part of the occiput shows where the specimen was not quite complete.
Fig. 7.—The mandible of the same specimen, from above. (From a skull in Smithsonian Collection.) Both figures life size, by the author.

depression is rather small, and separated from its fellow by a considerable distance, differing in this respect from the Gulls, where they meet in the median line.

Another extraordinary peculiarity of the skull of the Skimmer is the condition of the rostrum of the sphenoid, the interorbital septum, and the tumefied frontals. All these bones have a common cavity of no inconsiderable size, which, when opened, is found to be filled with a most delicate network of hair-like trabeculæ. This cavity communicates directly with the bodies of the lacrymals and the intertabular space of the cranial vault.

Thus it is seen that the interorbital septum is really double, and probably is never perforated by a foramen at its centre.

The optic foramen is small, and no doubt just large enough to assist the passage of the nerve. Each crotaphyte fossa is divided near its middle by a sharp, transverse crest, and these depressions are separated from one another behind simply by a raised median line. This arrangement is different from anything we find in the *Laridæ*, or any of the group that I have ever examined.

The mandibular articulation is peculiar in the extreme, for we find the postero-external angles of the basi-temporal triangle, descending as prominent processes, to have large elliptical facets at their extremities. These ellipses are placed with their major axes lengthwise, and they articulate with similarly formed surfaces on the inturned ends of the articular extremities of the mandible. Thus the mandible articulates in part with the *base of the cranium.* The posterior end of the outer facet of either quadrate faces directly to the rear, while in the Gulls it faces downwards and very slightly forwards.

In *Larus glaucus* these mandibular processes may also *meet* the prominences at the basi-temporal angles, but not to such an extent as we find in *Rhynchops*, nor is there a *true* articular joint present as in the latter form. This condition was overlooked by Coues in his description of the skull of *R. nigra*, as were several other important characters.

Still another singular condition is seen in the skull of the Skimmer not found in the *Laridæ*, and this time in the *vomer*. Now, although this bone agrees both in its method of articulation and general shape with the Gulls, Terns, and Jaegers, it is in the present form depressed at its extremity, swollen at the end, and clutched (thoroughly *anchylosed* in this individual) between the maxillo-palatines.

The skeleton of the lower mandible of this bird is so well known that, taken in connection with the two figures I present of it, renders any fuller description superfluous.

I will complete my remarks upon the descriptive part of the osteology of the *Laridæ* by presenting synopses of the typical characters of the skull in the Gulls, and the skull in *Rhynchops*, By typical characters I mean only such ones as will apply to the group at large, so far as I have been enabled to investigate it.

For reasons stated in the last paragraph the mandible will be omitted in this comparison, and my remarks confined exclusively to the cranium.

Typical Characters of the Cranium in the Laridæ and the Cranium in Rynchops compared.

Laridæ.—Superior osseous mandible, with anterior two-thirds of culmen nearly flat or broadly convex from side to side. External narial openings two-thirds as long as mandible, very large and open. Nasal processes of premaxillary distinctly retain their sutural traces throughout life. Cranio-facial region above, a simple, more or less well-marked, concavity.

Rynchops.—Superior osseous mandible, much compressed in a lateral direction, causing culmen to be almost cultrate both above and below, for its anterior two-thirds. External narial openings comparatively small; less than a third as long as mandible. Nasal processes of premaxillary lose their hinder sutural traces in the adult. A remarkably perfect and peculiarly formed cranio-facial hinge exists.

Laridæ.—Supraorbital glandular depressions meet in the median line of the frontal region. Crotaphyte fossæ do not meet behind.

Rynchops.—Supraorbital glandular depressions far separated in the frontal region. Crotaphyte fossæ do meet in the median line, being separated from each other by a fine line only.

Laridæ.—Interorbital septum a thin plate, always perforated at its centre.

Rynchops.—Interorbital septum *double* parallel plates, the intervening space filled in with very often cancellous tissue. Never perforated by a central foramen.

Laridæ.—Anterior extremity of vomer always free and terminated by a pointed spine. Maxillo-palatines encroach upon the interpalatine space.

Rynchops.—Anterior extremity of vomer thickened, seized between the maxillo-palatines, *and may anchylose with them.* Maxillo-palatines do not encroach upon the interpalatine space.

These are simply the principal characters to be taken into consideration in the comparison of the skulls of these birds. There yet remain, however, many lesser important differences in detail—as the form of the quadrate and the really extraordinary difference in the method of articulation of the mandible, and others, all of which have been sufficiently referred to already, and I purposely omitted them from the synopsis.

The present part will be followed by one more—or PART IX. —to complete this series of memoirs. In this concluding Part it is my intention to present a full account of the skeleton of *Chionis minor*, as in it I find many points that will be of great advantage to compare with the data brought out in the several other Parts of my work.

I think that our studies of the osteology of the groups we have had under consideration are now, perhaps, full enough to permit us to draw up a few conclusions as to the probable affinities of some of the families and subfamilies treated, at least in so far as their osteological characters seem to indicate them.

Further, not only will these skeletal characters be made use of, but I feel also that I am at liberty to avail myself of the additional advantage of having the skeletons of all the species we have described before me in greater or less number; and these always present to the mind a host of minor similarities or differences in details of form that no amount of mere description, or even actual illustration with the pencil, can ever convey, and which are sure and, if properly weighed, ought to influence us in our conclusions. I refer to the general *facies* of any skeleton—the *tout ensemble* of its characters.

When the mind is in possession of the salient characters which distinguish any two skeletons of more or less nearly related forms, it is very often the operation of this general sense of appreciation, of their affinity through an all-absorbing glance at their characters as a whole, which finally brings us to our conclusion as to their relationship.

Observations upon the Affinities of the Divers, Auks, and Gulls, as a Study of their Osteology seems to indicate them.

In speaking of the classification of the *Alcidæ* on a previous page, I have already advanced it as my opinion that of the American forms of Auks or Auk-like birds, the genus *Uria* presents in its skeleton, as *U. troile*, for example, the greatest number of characters held in common with the more typical representatives of the *Laridæ*. In other words, taking the Auks as a group and the Gulls as a group, and choosing *Uria* to represent the former and *Larus* the latter, they approach each other nearer at these points than through any other types we might select; and the relationship, so far as the skeleton seems to indicate, is by no means a very distant one. In one sense this draws the line between the Suborder PYGOPODES and the Suborder LONGIPENNES.[1]

The Gulls probably merge insensibly into the Terns, which latter are not entitled to more than subfamily rank. They should be followed by the *Stercorariidæ*, and these by the *Rynchopidæ*. Of the former I can say that a study of their skeletons shows that they are not far removed from some of the laridine forms, while I am not yet prepared to express myself fully as regards the *Rynchopidæ*. I have heard ornithologists say that *Rynchops* is nothing more than a Tern with an enlarged and flattened beak, fitted to meet the mode of life it leads. This is by no means the case, for the remainder of its skull at least is very different from that of a typical Gull or Tern. I prefer to make a personal examination of its entire structure

[1] The groups here spoken of as SUBORDERS were designated in the early parts of this series of papers as *Orders*, the change has been adopted to meet my more recent views.

before further committing myself to an opinion in regard to it. It certainly merits family rank.

So much for the classification of the North American LONGIPENNES.

Now, as to the Suborder PYGOPODES, I think, taking *all* we know of their structure into consideration, the Grebes no doubt represent the lowest types, in point of organisation, that we have among existing North American birds, and they have been assigned, very properly, a position in the system accordingly. Next to these undoubtedly stand the Loons, and when we come to give due weight to all the characters they present in their structure, we find them more nearly related to the Grebes than to any other group of existing water-birds. In some particulars the Loons and Grebes are widely separated, to be sure; but nothing like the gap that exist between the Loons and either the *Alcidæ* or *Laridæ*. So far as the skeletons go, the characters are ten to one in favour of the closer affinities of the *Podicipidæ* with the *Urinatoridæ* against the kinship of the latter with any other group.

I would suggest, then, and my suggestion is supported by the anatomical characters of the groups in question, that the Suborder PYGOPODES be made to contain the two super-families—(1) PODICIPEDES and (2) CEPPHI, the former for the Grebes and the latter for the Loons.

The gap between the Pygopodes and the Auks *is far greater*, as thus constituted, than the gap between the Auks and the Longipennes.

For the Auks, Murres, Puffins, and their allies, I would propose the Suborder ALCÆ to contain the four following families:—

1. FRATERCULIDÆ.
2. PHALERIDÆ.
3. ALCIDÆ.
4. ALLIDÆ.

These families will contain the same genera that the corresponding sub-families do, as at present arranged in the Check-List of the American Ornithologist's Union, and fully set forth in previous paragraphs of this work.

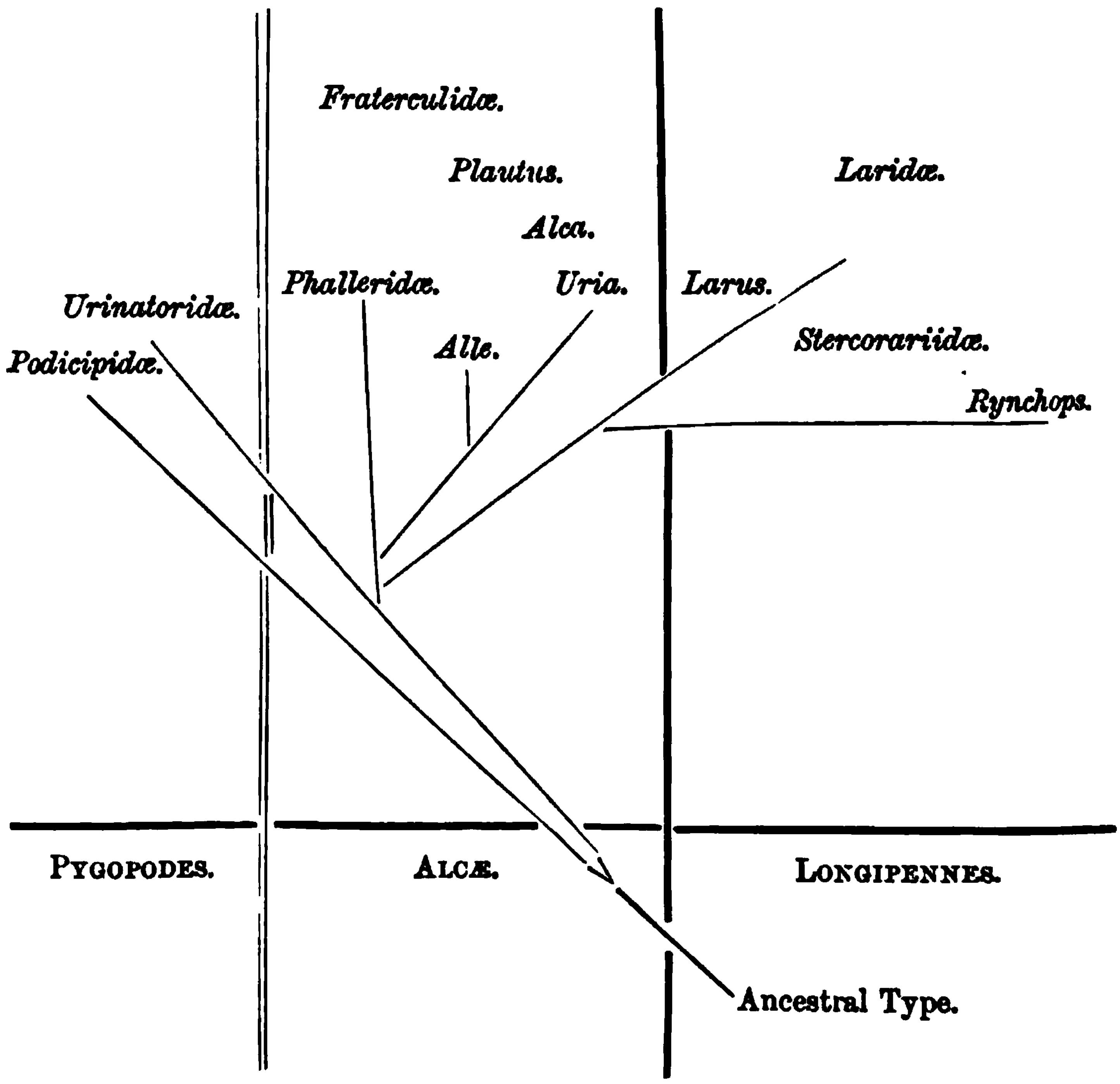
Moreover, they can be fully as well characterised, and better

in several instances, as the families at present composing the Suborder Longipennes.

Structurally, there is a far greater difference between *Fratercula arctica* and *Simorhynchus cristatellus* than we have yet been enabled to find between *Stercorarius pomarinus* and several of the laridine types.

Zoologists, in these days, seek the aid of a well-known class of diagrams to assist them in making clear to their readers such views upon the origin and descent of birds, or rather groups of birds, as I have attempted to present above.

Such a diagram will, I believe, help me in the present instance, and I herewith present the scheme I have gotten up, showing the probable descent and relationship of the Pygopodes, Alcæ, and Longipennes.



Through a footnote that appeared under Part VII. of the present series of papers, the writer has already stated that he is engaged upon a general treatise of the Osteology of the Birds

of the United States. In that work the classification of the Water-Birds will be still further elaborated, and his views of the taxonomy of the Class more extensively set forth. More particularly does this refer to the use of the groups designated as Orders, Suborders, and Superfamilies, as they apply to *Aves*.

It will be remembered that Huxley made three ORDERS of this class of vertebrates, but that it was Cope who, in 1889, created *four* SUPERORDERS for Aves, with numerous Orders and Suborders.

My views upon the classification of Birds partake more of what Huxley has said in the premises than they do of any other taxonomer.

THE PLANES OF SUBPERITONEAL AND SUBPLEURAL CONNECTIVE TISSUE, WITH THEIR EXTENSIONS. By WILLIAM ANDERSON, F.R.C.S., and GEORGE HENRY MAKINS, F.R.C.S.

THE subperitoneal and subpleural fasciæ are to be regarded as a portion of a wide system of mesoblastic connective tissue which surrounds the great vessels of the trunk, accompanying their branches from origin to termination, and extending, mainly in the form of perivascular sheaths, to all parts of the body.

The tissue varies considerably in different regions, sometimes forming a loose areolar network, sometimes condensed into more or less well-defined fascial laminæ, and in either case tending to become the seat of accumulations of fat. It is everywhere connected to the structures which lie external to or within it, either by means of delicate, easily torn fibres, or, in certain positions, by strong fibrous or fibro-muscular bands.

Histologically, it consists of an areolar stroma of fine fibres with an abundant development of the elastic element, intermingled in places with fat vesicles in larger or smaller quantity, and strengthened by bands of white fibrous tissue. Running in this meshwork may be seen an abundance of vessels and nerves, which are in part ancillary to the larger structures ensheathed.

So far as we have been able to discover, no general amount of this tissue has been published, but many scattered references to it are contained in the works of Luschka, Rüdinger, Henle, Hyrtl, Bourgery, Turner, Quain, Tillaux, Cunningham, Macalister, and others. The present contribution is an attempt to supply some links which have heretofore been wanting, and to describe the structure as a whole.

The *abdomino-pelvic* or *subperitoneal segment* of the tissue may be divided into two portions—a parietal layer, closely connected to the wall of the cavity; and visceral laminæ, which accompany the branches of the aorta to their distribution. From the abdomen it may be traced upwards into the thorax,

mainly through the aortic opening in the diaphragm, there becoming continuous with the "subpleural" tissue, and through that with the perivascular and perivisceral fasciæ of the neck, and with the vascular sheaths of the upper extremities; while in the other direction it descends to the lower limbs, where it is represented by an unnamed areolar tissue related mainly to the vessels of the parts, surrounding them with sheaths (which are quite distinct from the vascular interfascial clefts), and penetrating with them even into the muscles of the part.

The *parietal layer* is most largely developed in front of the vertebral column, where it surrounds the aorta and its branches, the great veins and their tributaries, the lumbar lymphatic glands, the sympathetic ganglia, and other contiguous structures. From this point it may be traced as a broad expansion between, and intimately connected with, the peritoneum on the one hand, and the transversalis, diaphragmatic, iliac, obturator, and recto-vesical fasciæ on the other, embracing all the various vessels, &c., which lie upon the posterior abdominal wall, and passing, as vaginal investments to certain of these, outside the limits of the cavity.

In its relations with the large vessels, it forms for each a definite sheath, in the substance of which ramify the nervi and vasa vasorum destined for the supply of the coats of the vessel. The inner surface of this sheath is separated from the tunica adventitia by a kind of lymph-space crossed by a multitude of fine elastic fibres, and by some stronger bands which convey vessels or nerves. A similar arrangement exists for the ureters, and for any nerve cords which run within the tissue, and the lymphatic glands are encapsulated in an analogous manner. Where a large artery and vein run together, the opposed sides of the respective investments may coalesce, presenting the appearance of a sheath subdivided into two compartments by a septum, and in like way are formed compound sheaths wherever a number of structures lie in close contact. Such an arrangement is found in connection with the external iliac vessels,—the vein, the artery, and a lymphatic gland or leash of lymphatic vessels occupying each a compartment of a sheath which, passing beneath Poupart's ligament, and receiving some accessory fibres from the fascia transversalis, becomes the "femoral

sheath." The femoral sheath, in fact, is a simple continuation of the aortic and iliac sheaths. The structure of the lumbar portion of the subperitoneal tissue is commonly obscured by the fat developed within its meshes, but in thin subjects it may be detached as a broad, thick, and strong layer of laminated fibrous tissue, pierced by the great vessels and by the ureters, and containing complex ramifications of arteries, veins, nerves, and lymphatics (fig. 1). Traced into the pelvis, it changes its character

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FIG. 1.—Sub-peritoneal Fascia detached from Posterior Abdominal Wall, with contained vessels, &c.

1. Aorta.
2. Inferior mesenteric artery.
3. Vena cava.
4. Spermatic vessels.
5. Ureter.
6. External iliac vessels in sheath (continuous with femoral sheath in thigh).
7. Lymphatic gland.

and there becomes somewhat loose and intermingled with a large quantity of soft fat, which forms a kind of ellipse around the pelvic viscera, separating them from the bony and muscular walls of the cavity, and by additional processes, from each other. This is well shown in Braune's *Atlas*, plate xx., and in Rüdinger, plate i. fig. *e*, part 4, and has been described by many writers.

In the rest of its extent, however, where it lies against the transversalis and diaphragmatic fasciæ it is relatively thin, and more free from adipose tissue. It should be noted, however, that the prevesical fat extends upwards behind the lower part of the recti, and that the peritoneum may here become separated from the abdominal wall by the ascent of the distended bladder, or by a pelvic abscess, which may thus show itself above the symphysis.

The *extra-abdominal prolongations* of the subperitoneal tissue are coextensive with the vessels and nerves that emerge from, or enter the cavity. Not only do the external iliac and the aortic openings transmit extensions, but the lumbar, sacral, gluteal, sciatic, pudic, and obturator vessels also carry their sheaths with them through the apertures by which they leave the abdomen and pelvis, while the spermatic vessels as they run in the inguinal canal and scrotum, and the round ligament in the female, are seen to be surrounded by fat-bearing connective tissue, which may be traced backwards to the same source. Abnormal extrusions of the subperitoneal tissue may also occur in connection with deficiencies in the abdominal parietes. Such fatty herniæ in the course of the linea alba are not very rare, and may easily lead to errors of diagnosis. It is also probable, as suggested long since by Roser and others, that the way for true visceral or omental herniæ may be prepared by the growth of fatty wedges of subperitoneal tissue through natural or adventitious apertures in the abdominal or pelvic wall.[1]

The *visceral* portion follows the course of the branches of the aorta. In the case of those viscera which lie in almost direct contact with the great vessels and posterior abdominal wall, such as the liver, the pancreas, the third portion of the duodenum, and parts of the colon, it passes at once on to them, fixing them in their places, becoming continuous with their connective-tissue tunic, following the supplying vessels into the substance of the organs, and, by means of the vascular plexuses lying within its meshes, establishing those important communications between parietal and visceral vessels, and between the blood supply of different viscera, to which Sir William Turner long

[1] This subject was discussed in an interesting communication to the Pathological Society by Mr Jonathan Hutchinson, junior, two years ago.

since drew the attention of anatomists.[1] The renal vessels conduct a layer generally containing much adipose tissue, and this

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FIG. 2.—Semi-diagrammatic view of the relations of the Subperitoneal Tissue to the Abdominal Vessels and Viscera.

1. Transverse colon.
2. Descending colon.
3. Peritoneum.
4. Anterior portion of fatty capsule.
5. Left kidney.
6. Peritoneal cavity.
7. Ascending layer of transverse mesocolon.
8. Duodenum (3rd stage) receiving attachment of the band of Treitz.
9. Portion of head of pancreas.
10. Superior mesenteric vein (artery to left).
11. Vena cava (aorta to left) imbedded in subperitoneal tissue.
12. Duodenum (2nd stage).
13. Gland.
14. Right kidney.
15. 2nd lumbar vertebra, upper surface.
16. Parietal layer of subperitoneal tissue.
17. Fatty capsule.
18. Ureter.
19. Renal vessels imbedded in subperitoneal tissue.

expanding over the entire organ forms its fatty capsule, which in the fœtus is partially separated from the parietal lamina of the

[1] *British and Foreign Medico-Chirurgical Review*, 1863 and 1865.

subperitoneal tissue by a distinct cleft (*see* fig. 2). The suprarenal bodies are in like manner covered by the tissue and fixed in their place, the right being firmly attached by it to the liver, the left to the diaphragm, as well as to their respective kidneys.

Those portions of the alimentary canal which are connected to the parietes by duplicatures of peritoneum are less obviously in touch with the subperitoneal fascia; nevertheless the connection although more distant is no less direct, and the tissue may be readily demonstrated passing between the serous laminæ as far as the tube, becoming most distinct in the triangular interserous space formed where the two peritoneal laminæ separate before embracing the gut, and fat may accumulate there in considerable quantity.

The connection between the parietal and visceral layers is greatly strengthened at one point by the strong suspensory band of Treitz, which, passing from the diaphragmatic fascia on the right side of the œsophageal opening, becomes firmly attached to the termination of the duodenum, and, as Mr Lockwood has already pointed out, runs between the layers of the mesentery —some fibres may also be traced to the transverse mesocolon. Besides these a rather strong process goes from near the promontory of the sacrum to the sigmoid flexure and rectum. In fact the whole of the membranous viscera are suspended by ligamentous bands which belong to the subperitoneal connective tissue.

The relation of the subpleural tissue or endothoracic fascia to the thorax is similar to that of the subperitoneal tissue to the abdomen. It is most abundant where it invests the contents of the posterior and superior mediastina. In the latter situation (*see* fig. 3) the great vessels and nerves, the thoracic duct, the œsophagus, and the trachea, lie embedded in a mass of connective tissue, which becomes condensed into sheaths where in contact with the various structures, and the sheaths are continued through the upper opening of the thorax to form what may be described as the visceral portion of the deep cervical fascia. Here, too, it becomes attached with especial firmness to the great veins, and by binding their walls to the adjacent structures aids in preventing their collapse when divided (a condition which, however, is essentially attributable to the resistance offered by the osseo-

cartilaginous circumference of the thorax to the atmospheric pressure). At the level of the bifurcation of the trachea the tissue passes on to the root of each lung, ensheathing and holding

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FIG. 3.—Upper Opening of Thorax seen from below, showing Endothoracic Fascia and Supra-Pleural Domes.

1. Visceral reflection of endothoracic fascia.
2. Parietal reflection.
3, 4. Subclavian vessels and their branches seen through dome of endothoracic fascia after removal subsequent pleura.
5. First rib.
6. Mediastinal tissue continuous with endothoracic fascia and deep portion of deep cervical fascia.
7. Manubrium. Cut surface below first rib.
8. Cartilage of first rib.
9. Internal mammary vessels.
10. Remains of Thymus.
11. Innominate vein.
12. Phrenic nerve.
13. Vagus nerve.
14. Common carotid artery.
15. Subclavian artery.
16. Trachea.
17. Recurrent laryngeal nerve.
18. Thoracic duct.
19. Œsophagus.
20. Sympathetic and first dorsal nerve.
21. Superior intercostal vessels.
22. First dorsal vertebra (lower surface).

together its various elements, penetrating with these into the parenchyma of the organ on the one hand, and on the other spreading in an attenuated form over its entire surface. The

œsophagus and vessels and nerves of the posterior mediastinum are invested in a similar manner, and a layer is prolonged forwards around the fibrous pericardium, binding down the phrenic nerve, and extending to the narrow anterior interpleural space behind the lower part of the sternum. In front it fixes the anterior fold of the pleura to the pericardium, and in its meshes are developed the large "plicæ villosæ" or "plicæ adiposæ" of Luschka, which extend over the anterior surface of the pericardium and the adjacent portion of the diaphragm.

The parietal layer in its costal portion is thin and loosely adherent to the thoracic wall, except where it passes with the intercostal vessels between the intercostal muscles to become continuous, around the perforating branches of the former, with the external thoracic connective tissue. Over the sternum it encloses the anterior mediastinal glands. Here, too, it is thicker, and is traversed above and below by strong fibres which pass from the sternum to the pericardium, and form the superior and inferior suspensory ligaments of the latter. Superiorly it crosses the inner surface of the first rib beneath and behind the anterior and middle scalenes and subclavian vessels, forming a dome over the cervical portion of the pleura and lung, to become continuous on the inner side with the visceral layer and adapt itself to the outer aspect of the mediastinal structures. Where it projects into the neck it generally receives the attachment of some fibres from the tendons of the anterior and middle scaleni, and a broad expansion from the scalenus quartus when this slip is present. Above it is so connected with the sheaths of the subclavian vessels, that care is necessary in passing an aneurism needle around the artery to avoid perforation of the endothoracic fascia, and injury to the pleura. The diaphragmatic portion of the parietal layer is very thin, except where plicæ adiposæ are developed, and where it is connected to the costal portion at the costo-diaphragmatic angle by the costo-diaphragmatic bands of Cunningham.

The subpleural mediastinal plexus (Turner) is comparable to the subperitoneal plexus mentioned on page 81, and provides a similar communication between the visceral and parietal vessels.[1]

In these endo-thoracic and intra-abdominal fasciæ we have

[1] *British and Foreign Medico-Chirurgical Review*, January 1865.

then a tissue which morphologically arises from the same embryonic layer as the vessels, and is destined to accompany and serve them wherever they go. It forms sustentacular sheaths for the vessels and nerves and various organs within the trunk, and follows them into the intermuscular spaces of the trunk, neck, and extremities, binding down the invested structures in such a manner as to maintain their due relations to each other and to the walls of the containing cavities, filling up the irregular spaces between them, and conveying to them their vascular and nervous supply. It affords a medium of communication between visceral and parietal vessels and between the vessels of different viscera. It has important suspensory functions in connection with the membranous and solid viscera, especially in the abdomen; and it serves as a storehouse for fat. Surgically, it explains the presence of mysterious deep fascial layers, the identity of which has often exercised the minds of operators in the course of the incisions for colotomy and nephrotomy.[1] Its relation to the subclavian artery on the one hand, and to the pleura on the other, may account for some of the casualties attached to the ligature of that vessel. Its continuity with the axillary fascia around the perforating vessels may explain the occasional pleuritic complications of axillary abscess; and its extension over the spermatic vessels may afford a solution to the problem of peritonitis following castration. Its laminated structure exercises an important influence upon the course of pathological exudations, especially in the mediastina and pelvis. Undue laxity of the tissue may favour displacements of certain organs, as in movable kidney, and, as Mr Lockwood has pointed out, in hernia. Its extrusion through normal or adventitious apertures in the walls of the thorax and abdomen may open the way for hernial protrusions, or may itself constitute a kind of hernia, as in the linea alba and elsewhere. A hernia may be reduced *en masse* between its layers; and, finally, it may serve as a nidus for fatty tumours and other morbid growths.

[1] In colotomy in thin subjects it often appears in the form of a transparent layer passing behind the colon, and simulating closely the parietal peritoneum.

ABNORMAL ARRANGEMENT OF THE ILEO-CÆCAL PORTION OF THE INTESTINE. By W. H. BENNET, F.R.C.S., *Surgeon to and Lecturer on Anatomy at St George's Hospital*, and H. D. ROLLESTON, M.A., M.B., M.R.C.P., *Curator of the Museum of St George's Hospital*.

WE have recently met with three examples of an abnormal arrangement of the ileo-cæcal portion of the alimentary canal which has not, as far as we can learn, been previously described.

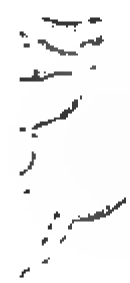


FIG. 1.—IL, ileum having a normal mesentery; IL^x, lower five inches of ileum devoid of mesentery (IL^x is placed near the junction of these two parts of the ileum); C, cæcum; V.A., vermiform appendix.

Our attention was first directed to the condition to be described, by the fact that it was associated with, and probably was instru-

mental in producing a fatal twisting of the lower part of the ileum.

The following is a description of the condition of the parts in the three specimens:—

The lower five inches of the ileum (IL[x]) had no mesentery. The peritoneum passed over and fixed the intestine firmly to the back of the abdomen. There was no sign of any inflammatory process having occurred.

This fixed part of the ileum begins at the right sacro-iliac joint and passes with a slight curve upwards over the right iliacus muscle to open into the cæcum.

The cæcum (C) has not descended into the right iliac fossa but lies over the right kidney.

The cæcum is small and is of the "fœtal type," the appendix vermiformis (V.A.) arising from the apex of the cæcum, and the pouches (or haustra) to the right and left of the anterior bundle of longitudinal muscular fibres (or tænia coli) being of equal size. The peritoneum passes over and binds the cæcum down, in the same way as it normally fixes the ascending colon to the back of the abdomen. The vermiform appendix has a mesentery as usual.

In these three specimens there was then a deficiency of mesentery from the lower five inches of the ileum which was situated in the right iliac fossa, associated with a fœtal cæcum which had not descended into the right iliac fossa but lay over the right kidney.

In one of these specimens the ileum had been sharply twisted on itself at the point where the portion of gut with a normal mesentery joined the lower five inches which lay fixed behind the peritoneum. The lumen of the gut was here obliterated. Above this obstruction the bowel was distended, while distally it was collapsed. It appeared probable that the twisting of the ileum had been favoured by the anatomical arrangement of the parts. This specimen was shown at the Pathological Society on May 20, 1890, and, together with a specimen which resembled it in every particular except the twist, at the meeting of the Anatomical Society on May 30, 1890.

REPORT OF THE COMMITTEE OF COLLECTIVE INVESTIGATION OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND FOR THE YEAR 1889–90. Reported by ARTHUR THOMSON, M.A., M.B., *Lecturer on Anatomy, University of Oxford.*

IN presenting this, the First Annual Report, it may be well to call attention to the steps that have been already taken to further Collective Investigation among the anatomical teachers of this country.

At a meeting of the Anatomical Society, held on March 6, 1889, it was agreed to appoint a Committee to consider a scheme of Collective Investigation.

In the month of September of the same year, this Committee issued the following questions:—

1. Abnormalities in the arterial supply of the kidney. The renal arteries to be noted in every subject dissected, and all deviations from the normal arrangement in number and position to be tabulated.
2. The relation of the internal maxillary artery to the external pterygoid muscle, whether superficial to, or deeper than the muscle, its position to be noted in each body.
3. The condition of the tuberculum laterale of the posterior process of the astragalus, whether detached as an os trigonum, or continuously ossified to the astragalus, its relations to the posterior astragalo-peroneal ligament may also be noticed.
4. The order of union of the three great trunks which form the vena portæ, and the levels of their junctions. The recorder is asked to endeavour, as far as possible, to observe and report the existence of valves in any of the tributaries of this vein.

Copies of the above were forwarded to the teachers in the following schools:—

*St Bartholomew's Hospital, London.
Charing Cross Hospital, London.
St George's Hospital, London.
Guy's Hospital, London.
King's College, London.
London Hospital, London.
St Mary's Hospital, London.
*Middlesex Hospital, London.
*St Thomas' Hospital, London.
*University College, London.
*Westminster Hospital, London.
London School of Medicine for Women.
Cook's School of Anatomy.
*University of Oxford.
*University of Cambridge.
*Queen's College, Birmingham.
Bristol Medical School, Bristol.
*School of Medicine, Yorkshire College, Leeds.
*School of Medicine, University College, Liverpool.
The Owens College, Manchester.
*University of Durham, School of Medicine, Newcastle-on-Tyne.
University of Edinburgh.
School of Medicine, Royal College of Surgeons, Edinburgh.
School of Medicine, Minto House, Edinburgh.
*University of Aberdeen.
University of Glasgow.
Anderson College, Glasgow.
St Mungo's College, Glasgow.
Western Medical School, Glasgow.
*School of Physic, Trinity College, Dublin.
Carmichael School of Medicine, Dublin.
Catholic University, School of Medicine, Dublin.
Royal College of Surgeons, Ireland.
Queen's College, Belfast.
Queen's College, Cork.
Queen's College, Galway.

Through error, notices were not sent either to University College, Dundee, or to the School of Medicine for Women, Edinburgh.

Answers were received from 13 of the 36 schools enumerated above, a fact which is noted by placing an asterisk before the name of the institution from which an answer has been received.

Whilst the Committee is gratified with the support they have received, they cannot but recognise the fact that many of the larger and more important educational bodies are conspicuous by their absence in the Report. The Secretary intimates that in several instances where the notices had been forwarded to the professors or teachers, these officers had not brought them under the notice of the gentlemen more immediately engaged in the direction of the practical work. As it is impossible in all cases to obtain accurate information as to the proper person to whom to address the notices, the Committee express the hope that in future the officials who receive the Society's notices will undertake to forward them to the proper quarter. Had such been done in the present instance, the Secretary has reason to know that the number of reports sent in would have been considerably greater. In view of facilitating the arrangements, the Secretary will be glad to receive any information as to the proper persons to whom to address the notices. Encouraged by the success of the present inquiry, the Committee, profiting by the experience of the past year, trust that next year they may look forward to receive the co-operation of a larger number of schools in the publication of their Report. Meanwhile, they wish to

place on record their thanks to the gentlemen who have so kindly assisted them upon the present occasion.

REPORT.

In dealing with the answers to the various questions, the Secretary has endeavoured, as far as possible, to arrange the results in tabular form. This has not always been an easy matter, hence the necessity of occasional notes in the Tables.

Prefixed to each Table is a paragraph explanatory of its arrangement, together with a summary of facts, the nature of which precludes the possibility of arranging them in tabular form.

Question 1.—Table I.

Nine reports have been sent in, in reply to Question 1, giving a total of 419 arteries examined.

The first column contains the names of the schools from which the reports have been received. Appended to each School is the name of the gentleman to whom the Society is indebted for their return. The succeeding eight columns are devoted to the enumeration of the different varieties recorded, each column being further subdivided into three for right and left sides and total respectively. When the figures in the R. and L. columns are linked together, thus (10—10), it implies that the arrangement is the same on both sides; when not so joined, it indicates that the arteries on the two sides of the same subject have differed. The last column on the right hand side of the table contains the totals of the different specimens examined in each school.

Mr C. Angus, in the Aberdeen report, cites a case in which the right renal artery gives off muscular branches to the right crus of the diaphragm. Referring to the case of three renal arteries on both sides in the same report, Mr Angus writes—"The left is supplied by three arteries coming off separately from aorta. The upper (much the larger) arose 1″ below the cœliac axis, the lower one ½″ below this point. Right supplied by three from aorta, all arising close together, middle the larger."

In the Trinity College, Dublin, report, forwarded by Professor Cunningham, in the cases recorded in columns 3, 4, and 5, the accessory arteries entered the kidney at the upper and lower borders of the organ, in column 6 the arteries enumerated entered the hilum.

Quoting from the same report, the following is interesting:—

"In regard to the relations of the artery, vein, and ureter, the varieties were arranged into six classes for convenience.

"*Class* 1. In this the arterial trunk arising from the aorta passed

outwards behind the vein, its branches entering the hilum between the vein and ureter. Of this variety, fifty-two instances were noted.

"*Class* 2. In which the trunk of the artery passing outwards behind the vein broke up into branches, which enclosed the ureter at the hilum. This condition existed in twenty-one cases.

"*Class* 3. In this the artery passed out behind the vein, but its terminal branches in entering the hilum enclosed that vessel. Of this variety, twelve instances were noted.

"*Class* 4. In which the course of the artery lay behind the vein, but its terminal branches enclosed both the vein and ureter at the hilum. Eight cases fell into this category, in five of which there was also a branch entering between the vein and ureter.

"*Class* 5. In which the artery coursed outwards altogether in front of the vein, its branches retaining the same position at the hilum. Eight cases of this variety were also noted.

"*Class* 6. In which the artery passed outwards behind the vein, but its branches entered the hilum altogether behind the ureter. Only two instances were noted."

Mr H. D. Rolleston, in the St Bartholomew's Hospital return, notes the fact that in seven subjects the arterial supply was normal on the right side, whilst on the left, two renals were present. In the subject with the three renals on the right side, there were two renals on the left, and in that with four arteries on the left, there were two on the right side.

In the report forwarded from University College, London, by Professor Thane, Mr E. W. Selby describes a case in which "the right kidney was large, and was supplied by a single artery; the left kidney was very small, crescentic in shape, and each extremity received a small vessel, the upper arising from the back of the aorta opposite the renal artery, the lower from the front of the aorta ½ an inch above its bifurcation." In the instance recorded in this report of the occurrence of three arteries on the left side, there was but one on the right side.

Mr F. G. Parsons, F.R.C.S., in the St Thomas' Hospital report, summarizes the details as follows:—"Out of thirty bodies examined, nine displayed abnormalities in the arterial supply of the kidneys. In six subjects the arteries were abnormal on one side only; of these, three were on the right and three on the left. In the other three cases, both sides were abnormal. Mr Parsons also draws attention to the fact that in four cases in which an accessory renal artery comes from above the proper renal, the accessory trunk crosses obliquely in front of the renal artery, and enters the lower part of the organ just below the hilum; in two instances it supplies offsets to the ureter."

One of the cases noted in this report is interesting. It is described as follows:—"Movable kidney on the right, having three renal arteries, one from the aorta and one from each common iliac."

In one of the diagrams with which Mr Parsons illustrates his report, the ureter is represented as double for a considerable distance on the right side.

Mr W. Thelwall Thomas, F.R.C.S., notes the following in the

report from University College, Liverpool:—"Right kidney three arteries, the uppermost corresponding to the normal position, the lowest being ½ an inch from the bifurcation. The ureter *is in front*, the vena cava *behind*.

In a report received from Queen's College, Birmingham, mention is made of two cases of double renals in different subjects. In one, on the left side, the arteries arose from the aorta 10 mm. and 8·5 mm. respectively above the bifurcation. In another subject there were two renal arteries on the right side. These cases are not included in the Tables, as unfortunately there was no record sent of the number examined.

[TABLE I.

TABLE I.—*Abnormalities in the Arterial Supply of the Kidney. The Renal Arteries to be Noted in every Subject dissected, and all Deviations from the Normal Arrangement in Number and Position to be Tabulated.*

	(1) Normal.			(2) Single Artery undergoing immediate division.			(3) 			(4) 			(5) 								arise.	(8) Four Arteries.			(9) Total number examined.
	R.	L.	[redacted]	R.	L.	Total.	R.	L.	Total.	R.	L.	Total.	R.	L.	Total.						Total.	R.	L.	Total.	
	10—10 7	5	33	2 dividing into 2, 1 into 3.	1 dividing into 2.	4	1	3	4	1	3	4	.	.	.						3	1	.	1	51
	2—2 .	2	6	1	1	2	2	.	2	.	.	.	.	.	.						.	.	.	.	10
	10—10		20	.	.	.	.	.	.	.	.	.	.	.	.						2	.	.	.	22
	.	.	76	.	.	.	.	.	10	.	.	4	.	.	1						5	.	.	1	103
	12—12 7	3	34	.	.	.	.	.	3	.	.	3	.	.	.						1	.	1	1	55
	9—9 4	.	22	.	.	.	1—1		2	.	2	2	.	.	.						1	.	.	.	29
	.	.	46	.	.	.	2—2	3	7	1—1		2	2	.	2						1	.	.	.	60
	8—8 1	4	21	2 splitting into 2.	.	2	.	.	.	.	.	.	1	.	1		inf. mesenteric.		from inf. mesenteric.		1	.	.	.	33
	.	.	53	.	.	.	.	1	1	1	1	2	.	.	.	.	.	.	2	.	2	.	.	.	58
Total, ...	.	.	312	.	.	8	.	.	29	.	.	17	.	.	4	.	.	39	.	.	14	.	.	3	419
Percentage, . .	.	.	74·4	.	.	1·9	.	.	6·9	.	.	4	.	.	9	.	.	7·6	.	.	3·3	.	.	·7	100

QUESTION 2.—TABLE II.

Answers to Question 2 have been received from thirteen schools, comprising in all 447 observations.

The division A in the Table includes a record of all the arteries examined. The first column includes the total number examined in each report, the two succeeding columns being devoted to those cases in which the artery is superficial, or deep, as the case may be. Each column is further subdivided so as to allow of the grouping of the cases into left and right, the total in each case being given in larger figures. Division B includes those cases only which were examined on both sides. The figures here refer to the number of subjects examined, *not to the arteries*. This is further subdivided into columns, in which are noted the totals, the numbers of those superficial and deep on both sides, and the instances in which there is a variation in the arrangement of the artery on the different sides. Unfortunately the data forwarded are not in all cases sufficient to yield a complete return, but it has been thought well to tabulate such facts as have been stated. The last division has been devoted to "remarks." These chiefly refer to the relations of the artery to the various nerves in this region.

In the Trinity College report, Mr J. J. Long cites two cases in which the artery pierced the lower head of the muscle, and then became superficial to it, thus pursuing an intermediate course. In another case the artery pursued a very irregular course. It first passed deeper than the muscle, piercing the inferior dental nerve; it then coursed upwards, appeared above the superior head of origin of the pterygoid, whence it curved downwards and forwards, passing between the two heads of the muscle to enter the spheno-maxillary fossa.

[TABLE II.

TABLE II.—*The Relation of the Internal Maxillary Artery to the External Pterygoid Muscle, whether superficial to, or deeper than, the Muscle, its Position to be noted in each Body.*

Includes all Arteries examined.						B. Includes only those examined on both sides.			
Artery superficial to muscle.			Artery deeper than muscle.			Total.	Superficial.	Deep.	Different on two sides.
R.	L.	Total.	R.	L.	Total.				
17	17	64	9					3	.
3	6	9	4					2	.
7	6	13	1					.	8
5	5	10	12					12	.
23	24	47	25					.	.
.	.	118	.					.	.

Lingual ne

artery in thirty-six instances.

TABLE II.—*continued.*

Reports.	TOTAL	A. Includes all Arteries examined.						B. Includes those only examined on both sides.			
		Artery superficial to muscle.			Artery deeper than muscle.						
		R.	L.	Total.	R.	L.	Total.	Total.	Superficial.	Deep.	Different on two sides.
Brought forward,	214	.	.	113	.	.	97				
St Bartholomew's Hospital, London—H. D. Rolleston,	38	10	5	15	11	12	23	10	3	7	1
University College, London—H. A. Ballance,	38	9	4	12	15	8	26	12	3	6	3
St Thomas's Hospital, London—F. G. Parsons, F.R.C.S.,	30	6	8	14	9	7	16	.	6	6	4
Middlesex Hospital, London—C. Gordon Brodie, F.R.C.S.,	30	4	5	9	11	10	23	.	8	9	3
Westminster Hospital, London—Dr James Black,	.	.	.	.	.	.	.	.	.	.	.
University College, Liverpool—W. Thelwall Thomas, F.R.C.S.,	60	.	.	56	.	.	5	.	.	2	.
Yorkshire College, Leeds—W. J. Oliver,	32	9	9	18	7	7	14	.	8	6	1
Queen's College, Birmingham—Dr A. E. Mahood,	7	.	.	6	.	.	1	.	.	.	.
Total,	447	.	.	243	.	.	200	.	.	.	.
Percentage,	100	.	.	54·3	.	.	44·7	.	.	.	.

Of those cases in which the artery passed under the muscle, it was noted that in four instances it passed in front of the branches of the 5th nerve; in one it passed behind the inferior dental nerve and lingual nerve; in three it passed over the lingual and under the inferior dental nerve.
In the case where the artery was deep it lay between the inferior dental and lingual nerves.

Ten replies in all we
examined. The arran
Any observations by t
column of "remarks."

TABLE III.—*The condition of the Tuberculum laterale of the posterior process of the Astragalus, whether detached as an os trigonum, or continuously ossified to the Astragalus; its relations to the posterior Astragalo-peroneal ligament may also be noticed.*

Reports.	Total Number of Specimens Examined.	Evidence of Separate Centre of Ossification.	Os Trigonum Separate and Distinct.	Remarks.
University of Cambridge—W. C. Melsome,	28	.	4	Two detached on same subject. The others right and left in different subjects.
University of Oxford,	14	1		In two cases the tuberculum laterale was of unusual size.
University of Durham, College of Medicine, Newcastle—Dr Howden,	8	.	.	
University of Aberdeen—C. Angus, M.B.,				
Trinity College, Dublin—C. E. Stokes, B.A.,				
University College, London—Percy Fleming, M.D., F.R.C.S.,				
St Thomas's Hospital, London—F. G. Parsons, F.R.C.S.,				
Middlesex Hospital, London—C. Gordon Brodie, F.R.C.S.,				
Queen's College, Birmingham—Dr A. E. Mahood,				
Yorkshire College, Leeds—M. J. Oliver,				
Total,				
Percentage,				

Question 4.—Table IV.

From the nature of the inquiry, the returns in this case are not so numerous. Seven schools only have sent in reports, with a total of 118 cases examined.

The first four columns in the Table explain themselves. The fifth is devoted to a tabular view of the point of formation of the portal vein. This column has been subdivided into four wide spaces and three narrow spaces. The wide spaces represent the vertebræ from the 12th dorsal to the 3rd lumbar, the intervening narrow spaces, the intervertebral discs. The figures (which indicate the number of cases noted) are placed in these wide and narrow columns according as the point of formation of the portal vein corresponds to the level of a vertebra or a disc, the vertebræ in each case being numbered at the upper end of the column. When the figures are placed more to the right or left sides of the wide columns, it implies that the point of formation of the vein lay more to the lower or upper border of the vertebra respectively.

Mr W. C. Melsome, in the Cambridge return, notes the fact that in nine cases the inferior mesenteric joined the superior mesenteric about an inch below and to the right of the superior mesenteric artery and opposite the 2nd lumbar vertebra.

In the Durham report, there is no record of any valves being found, though sought for in each instance.

In the Trinity College report, the following facts are worthy of quotation:—

"With regard to the exact point at which the veins united, it was found that the *inferior mesenteric* vein entered the *splenic vein* in 19 cases between $\frac{1}{2}$ and $\frac{3}{4}$ of an inch from its termination, in 10 cases about an inch, and in 4 cases at $\frac{1}{4}$ of an inch or under, from its termination, three of these were at the angle. When the *inferior mesenteric* joined the *superior mesenteric*, it did so in 11 cases about $\frac{1}{2}$ an inch, in 8 cases about $\frac{1}{4}$ of an inch, and in 3 cases over $\frac{1}{2}$ an inch from its termination."

In all cases the portal vein was formed behind the head of the pancreas.

Professor Cunningham appends some notes on observations concerning the mode of termination of the superior gastric or coronary vein.

Forty-eight subjects were examined with this object; 22 were males, and 26 were females.

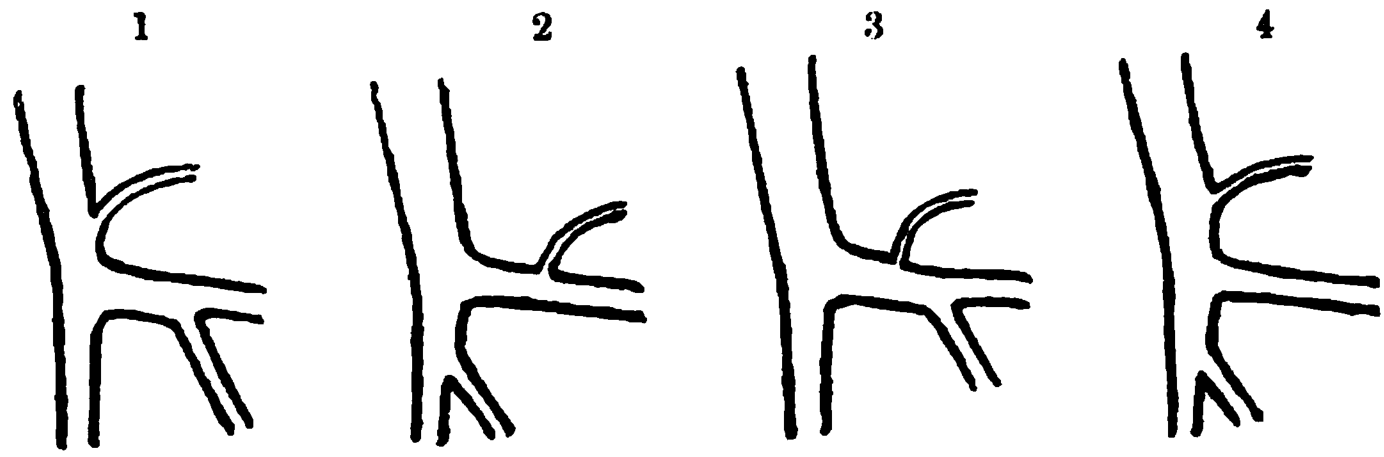
The manner of ending was as follows:—

(*a*) *In the Portal Vein.*—This occurred in 29 subjects; 15 of these were males, 14 were females.

(*b*) *In the Splenic.*—This obtained in 19 subjects; 12 females, 7 males.

In 47 of these cases the termination of the inferior mesenteric vein had also been observed, which, taken with the above, brought out the fact that there were four chief ways in which the portal vein may be formed (Diagram, page 100).

1. The most frequent method is that which is described as normal, —where the inferior mesenteric vein enters the splenic, while the



superior gastric enters the portal vein. This condition existed in 18 out of the 47 subjects—9 males and 9 females.

2. The next most frequent mode is that which may be called the reverse of the first, where the inferior mesenteric vein joins the superior, while the superior gastric enters the portal (splenic ?). This occurred in 11 of the subjects—9 females and 2 males.

3. In this mode of formation, both the inferior mesenteric and superior gastric veins poured their blood into the splenic. In 8 subjects this condition existed, 4 being males and 4 females.

4. Here, neither the inferior mesenteric nor gastric veins entered the splenic, but both these, together with the splenic vein, successively joined the continuous trunk of the superior mesenteric and portal veins. This obtained in 7 subjects—3 males and 4 females.

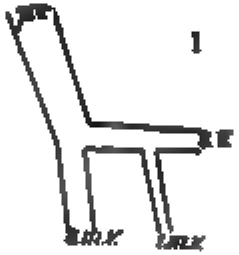
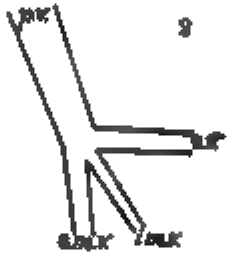
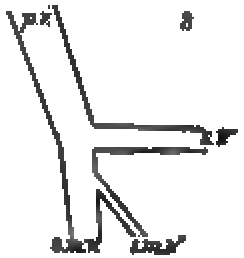
As noted in the Table, Mr Bunch, in the University College, London, reports, records the fact that out of 14 cases examined, the coronary (superior gastric) joined the portal in 11 instances—in 3 subjects the coronary vein joined the splenic.

It has been decided not to attempt to analyse the results, or compare them with previous observations. The Committee, being of opinion that this may best be left to those interested in such work, content themselves with publishing what they have reason to believe is a valuable series of reliable statistics.

In conclusion, the Secretary regrets that he has not received many suggestions for the inquiry for the ensuing year. Any communications regarding this or other business of the Committee of Collective Investigation should be addressed to him, at the Museum, Oxford.

[TABLE IV.

TABLE IV.—*The Order of Union of the three Great Trunks which form the Vena Portæ, and the levels of their functions. The recorder is asked to endeavour, as far as possible, to observe and report the existence of valves in any of the tributaries of this vein.*

Reports.		1 	2 	3 	Point of Formation of Portal Vein. Vertebræ. Dorsal. XII.	Disc.	Lumbar.						I.	Remarks.
University of Cambridge—W. C. Melsome, . .		11	1	9	.	.							.	
University of Oxford—	4	4	.	.	.	.							.	No valves; in two cases the coronary vein joins the portal.
University of Durham, Coll. of Medicine, Newcastle—Dr Howden, . . .	5	5	.	.	.	(1.)							.	
University of Aberdeen—C. Angus, M.B., . .	8	4 The inferior mesenteric joins the splenic at points varying from ¼" to 3½" to left of point of formation of portal vein.	.	4 Inferior mesenteric joins superior mesenteric from 1" to 3" below point of formation of portal vein.	(7.)	(1.)							.	No valves observed.
	55	33 (Males, 19; Fem., 14).	3	22 (Males, 4; Fem., 18).	.	.							(1.)	Eighteen were examined for valves; none found.
	14	9	2	3	.	.							.	Coronary vein joins portal in 11 instances.
	8	5	2	1	Apposite head of Pancreas, ... Apposite upper border of body of Pancreas . Behind body of Pancreas, ... Lower border of body of Pancreas, . . .								3 3 2 1	Coronary vein joins splenic in 3 instances.
	118	71	8	39	(7.)	(2.)	(1.)	(1.)	(4.)	(6.)	(85.)	(5.)	(1.)	
	100	60·1	6·7	33	.	.	.	.	.	.	.	.	.	

NOTE TO FIGURES:—*p.v.*, portal vein; *s.v.*, splenic vein; *s.m.v.*, superior mesenteric vein; *i.m.v.*, inferior mesenteric vein.

NOTE ON THE DISSECTION OF FLAT-FOOT.

By PROFESSOR HUMPHRY.

THE dissection of a third case of flat-foot from an adult is confirmatory of the observations made on two former cases described by me in this *Journal*, vol. xxi. pp. 159 and 162, and gives one or two further points of interest.

First.—The flattening of the sole, caused by preternatural extension, or yielding, of the middle transverse tarsal joint, with stretching and thinning of the calcaneo-scaphoid and calcaneo-cuboid joint, has allowed the tuberosity of the scaphoid bone and the ball of the astragalus with the sustentaculum tali, on the inner side, and the calcaneum and the cuboid, on the outer side, to rest upon the ground, and has converted the concavity of the plantar arch into a convexity.

Secondly.—This joint also bulges inwards, so that the inner border of the foot is convex instead of concave, the metatarsal bones slanting *out*wards and forwards instead of *in*wards, and the os calcis slanting slightly *out*wards and backwards. Hence a line drawn directly forwards from the bearing point of the heel, although that bearing point is on the inner side of the inner tubercle, traverses the third metatarsal bone instead of passing between the first and second metatarsal bones.

Thirdly.—In consequence of the lowering of the inner and fore—the sustentaculum tali—part of the os calcis which, in the falling plantar arch, takes place to a greater extent than that of the outer or cuboid part of the bone, forasmuch as it normally occupies a higher level, the os calcis is rolled over inwards, or superpronated, its outer tuberosity is raised quite above the ground and the inner side of its inner tuberosity rests upon the ground. Hence the outer surface of the bone is directed *up*wards and presents a concave, smooth, articular facet, upon which the blunted and convex lower end of the fibula rested and played. The weight of the limb was evidently, in considerable measure, borne upon this new joint, and transmitted through the fibula which is increased in thickness.

Fourthly.—The descent of the sustentaculum tali, with the

consequent rolling over of the os calcis, gives an obliquity to the joints of this bone with the astragalus, and to the upper articular surface of the astragalus, which must have been associated with some slanting inwards of the leg from the ankle, and probably a slight amount of "knock-knee." I infer this to have been the case, because the obliquity of the astragalus and the elevation of the outer edge of its tibial articular surface, is not (as in the specimen described, vol. xxi. p. 160, at any rate not so fully) counteracted by the rotation of the astragalus upon the os calcis.

Fifthly.—A slight diminution of the upper articular surface of the astragalus in front and behind, and the encroachment upon it of synovial tissue (as noted in the cases described, vol. xxi. pp. 158 and 160), indicates a corresponding limitation of the flexion and extension of the ankle-joint.

Sixthly.—A considerable bony growth upon the fore part of the neck of the astragalus, mounting up from above the anterior articular surface, and adapted to a corresponding flattened growth upon the surface of the scaphoid, presented an effectual block to further extension of the joint (similar growths were noted in the cases before described). There are also similar opposed and mutually flattened and adapted outgrowths upon the approximated upper articular margins of the os calcis and the cuboid bone.

The cartilages upon the articular surfaces of these joints are, at their upper parts, supplanted by soft granular extensions of the synovial membranes, which presented fringe-like processes into the joints. The cartilages are generally thin, and that upon the under surface of the ball of the astragalus, lying upon the stretched and thin calcaneo-scaphoid ligament, has quite disappeared, as also has that from the under part of the cuboid surface of the os calcis, which has come to rest upon the stretched calcaneo-cuboid ligament.

Seventhly.—An unusual bulging about the lower epiphysial line of the tibia, especially in front and still more behind, indicates that the condition of flat-foot took place in early life, probably at the usual period, viz., in boyhood, and that the growth at this line was affected by the loss of elasticity consequent on the loss of the plantar arch.

The plantar arch results chiefly from formation of the transverse tarsal joint which, by its convexity *up*wards and slightly *out*wards, is constructed to bear the weight of the limb directed *down*wards and slightly *in*wards upon the foot; and it is much dependent for its strength upon the subjacent ligaments, muscles, tendons, and fasciæ. When these are abnormally contracted, as in infantile paralysis of the leg and foot, the joint is abnormally flexed—hollowed beneath and on the inner side—producing "*pes cavus.*" When, on the contrary, these are relaxed, the joint yields under weight, is abnormally extended, bulging downwards and inwards, becoming convex instead of concave in these directions, constituting "flat-foot." The arrest of this latter deformity, as we have seen, results from the resting of the joint upon the ground and from the upgrowths from the approximated edges of the bones. A good working foot is thus secured, although the elasticity and fulness of the step are much curtailed, in cases which have been neglected or in which treatment by lessening the periods in which weight has to be borne, by affording support beneath the arch, and by strengthening the subjacent structures through appropriate exercise, has been ineffectual.

THE CONVOLUTIONS OF THE BRAIN: A STUDY IN COMPARATIVE ANATOMY. By Professor Sir WM. TURNER, M.B., D.C.L., LL.D., F.R.SS. L and E.

THE theme, "The Convolutions of the Brain," on which the Committee of Organisation of the Anatomical Section has done me the honour to invite me to address the Section on this occasion,[1] is one of profound interest to the physiologist, the psychologist, the pathologist, and the physician. But their respective studies of the functions and diseases of the cortex of the hemispheres cannot be satisfactorily conducted without the aid of the morphologist. So complex is the surface of the human brain that the signification of its various parts cannot be properly understood without constant reference to the appearance and arrangement of the surface of the hemispheres in other vertebrates, more especially the Mammalia.

The subject is one of so great an extent that I cannot do more in the limited time at my disposal than give a mere sketch of the arrangement of the grey cortex in specimens selected from different orders of mammals. Want of time will also prevent me from entering into a detailed analysis of the work of the numerous anatomists who have contributed to our present knowledge of the subject. I should wish, however, to pay my respectful tribute to the labours of Foville, Leuret, Gratiolet, Gervais, Broca and Beauregard, in France; of Rolando and Giacomini, in Italy; of Tiedemann, Burdach, Rudolph Wagner, Ecker, Bischoff, Pansch, Benedikt, Meynert and Krueg, in Germany; of Guldberg, in Norway; of Burt Wilder, in the United States; of Owen, Huxley, Flower, Rolleston, Marshall, Garrod, Ferrier and Cunningham, in Great Britain.

[1] This Address was delivered to the Anatomical Section of the Tenth International Medical Congress in Berlin, on Tuesday, August 5, 1890. It was illustrated by a series of fifty large diagrams, most of which were made by Mr Herbert Goodchild from my original dissections, and the same gentleman has drawn from nature, in pen and ink, a large proportion of the figures with which the Address, as now published, is illustrated. I have to thank him for the great care he has given to the preparation of the drawings. I have also to thank my Museum assistant, Mr James Simpson, for the efficient way in which he exposed so many of the brains within the cranial cavity.

When the surface of a cerebral hemisphere is carefully examined, it is seen to be capable of a natural division into two parts: a basal region, or Rhinencephalon, and a superior portion, or Pallium The demarcation between these two parts is due to the presence of a fissure, more or less distinctly defined in different animals, which has been named the *rhinal* or *ecto-rhinal* fissure. Our knowledge of this division is based upon the study of the development of the brain in different animals, as well as upon its comparative anatomy. It has been distinctly recognised by Owen and other anatomists. Broca wrote two admirable memoirs[1] on the subject, and laid especial stress on the modifications in the size of the rhinencephalon, or olfactory part of the brain, in the Mammalia. He has classified the Mammalia, in relation to the magnitude of their olfactory apparatus, into two groups: osmatic mammals, which possess a well-developed rhinencephalon with a keen sense of smell, and anosmatic mammals, in which the rhinencephalon and olfactory sense are either feeble or not developed at all. This classification is, however, logically defective, because in one and the same group are included both mammals which have the sense of smell, though it is not in them a dominant faculty, and mammals which are destitute of olfactory organs. I propose, therefore, to modify the classification of Broca, and to arrange the Mammalia in relation to the development of the olfactory apparatus into three groups:—

(*a*) Macrosmatic, where the organs of smell are largely developed, a condition which is found, for example, in the Ungulata, the proper Carnivora and indeed in the majority of mammals.

(*b*) Microsmatic, where the olfactory apparatus is relatively feeble, as in the Pinnipedia, the Whalebone Whales, Apes and Man.

(*c*) Anosmatic, where the organs of smell are apparently entirely absent, as in the Dolphins, and it may be in the Toothed Whales generally, though, as regards some genera of Odontoceti, we still require further information.

[1] "Le grand lobe limbique et la scissure limbique," *Revue d'Anthropologie*, 1878; and "Recherches sur les centres olfactifs," *Revue d'Anthropologie*, 1879.

RHINENCEPHALON.

The separation of the rhinencephalon from the pallium or cerebrum proper by a rhinal fissure is fundamental, and is seen, even in the lowest vertebrates. In *Petromyzon*, for example, the division is distinct, and the rhinal or ectorhinal fissure is present.

Amongst the Mammalia the extent and depth of the rhinal fissure (*r*) varies materially. In a number of mammals, as *Echidna*, *Phalangista*, *Halmaturus*, *Macropus*, *Lepus*, *Cholœpus*, it extends continuously, near the lower boundary of the hemisphere, from its anterior to its posterior end, as a well-defined fissure. In *Talpa* it is shallow, and passes from before backwards for about two-thirds the antero-posterior diameter of the hemisphere. In *Arvicola*, *Pteropus* and *Cynonycteris*, it extends for scarcely one-third the distance. In *Dasypus* it is divided into short anterior and posterior segments, not continuous with each other, and a similar arrangement is to be seen in *Sciurus*. In the Carnivora and Ungulata, owing to the considerable development of the pallium, the tendency of the fissure is to pass from the lateral to the inferior surface of the hemisphere. In Apes and in Man, from the great reduction in size of the rhinencephalon, the rhinal fissure is limited to the region of the Sylvian fossa.

The rhinencephalon consists of an olfactory bulb, a crus or

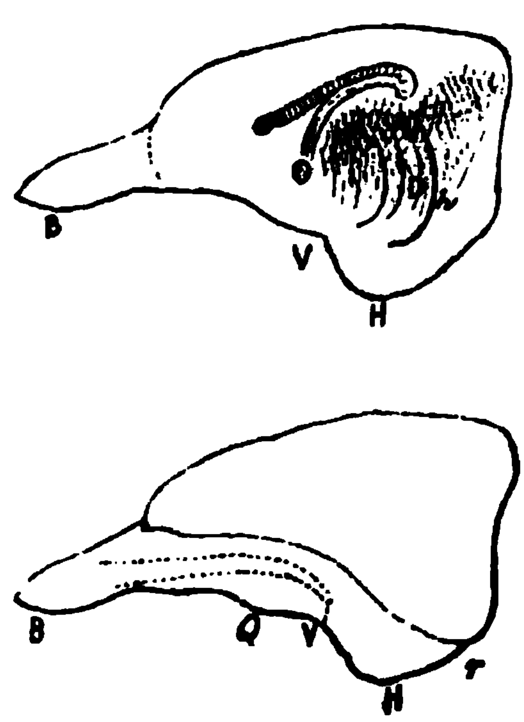


FIG. 1.—Hemisphere of macrosmatic Rabbit. The upper figure is the mesial surface, the lower the cranial surface.

peduncle, and a lobus hippocampi, which vary in appearance,

position, and size in different mammals. In *Echidna* they present a grey surface, so that the lobus and crus look like a continuous convolution. Usually, however, white bands appear on the surface of the crus, which, in the Horse, Dog, and other macrosmatic mammals, are of considerable breadth. Even in such small brains as those of the Rabbit and Marmot slender white bands can be seen on the surface of the crus. In the human brain, and those of Apes, the surface of the crus is composed of white matter, similar in appearance to that of the external and internal roots of the olfactory peduncle.

The *bulbus* (B) is the most anterior part of the rhinencephalon. As its name expresses, it has a bulb-like swelling, and, except in Man and the higher Apes, projects forwards or upwards in front of the anterior end of the hemisphere.

The *crus* or *pedunculus* is, as a rule, separated from the bulbus by a constriction. In Man, Apes, Seals and Whalebone Whales it is slender and stalk-like. But in most mammals, as is well seen in the Ungulata, it is thick and band-like. Immediately in front of the area known in human anatomy as the *locus perforatus anticus*, but to which, in the comparative description of this part of the brain, the name of *quadrilateral space* (Q) is frequently applied, the olfactory peduncle divides into roots. Two of these are visible on the surface. They are called external and internal, and the external (*ex*), which is larger and more distinct than the internal (*in*), forms the outer boundary of the quadrilateral space, and in most mammals can be readily followed backwards into the lobus hippocampi.

The *lobus hippocampi* (H), called also natiform protuberance, or lobus pyriformis, is of great importance, for it is the central origin of the outer root of the olfactory peduncle. It forms a well-marked eminence in the brains of mammals generally. In the lower mammals, whether smooth-brained, as in *Lepus* and *Talpa*, or convoluted as in *Echidna* and *Macropus*, it is at the basal part of the hinder end of the hemisphere, and visible at the side when the hemisphere is seen in profile. In the Ungulata, and in such Carnivora as the Dog, it is best seen on the basal surface; for, owing to the development of the pallium backwards and downwards, it is no longer at the posterior end of the hemisphere, and is only partially seen on the lateral

aspect. In the Walrus and Seals (fig. 2) the still greater development of the pallium has thrown it towards both the basal and the inner surface of the hemisphere. In Man and Apes, where it is known as the *uncus* or *unciform convolution*, it is

FIG. 2.—Basal surface of the brain of the microsmatic Elephant Seal (*Macrorhinus leoninus*).

entirely on the inner surface of the hemisphere, and is concealed both laterally and inferiorly by the enormous development of the temporo-sphenoidal lobe. Hence the lowest part of the hemisphere in this region is not formed by the same structure in all the Mammalia. In the more lowly organised brains the lobus hippocampi is the most depending part, but in the higher brains the convolutions of the temporo-sphenoidal lobe project downwards beyond it.

Its size, in relation to that of the entire hemisphere, varies much in different mammals. In the smooth-brained Insectivora and Rodentia, for example, the lobus hippocampi forms a con-

siderable proportion of the hemisphere. In an *Erinaceus europæus* (Hedgehog) its greatest vertical diameter was 7 mm., whilst that of the pallium was only 8 mm. In a *Talpa europæa* (Mole), their vertical diameters respectively were 3 and 6 mm. In a Rabbit the greatest vertical diameter of the lobus was 8 mm., that of the pallium 16 mm. In a Marmot (*Spermophilus*) their corresponding respective diameters were 7 mm. and 16 mm.

As the brain becomes convoluted, the pallium increases in size in a much greater ratio than the lobus hippocampi, until in the higher brains the lobus forms but a very small proportion of the hemisphere. This is especially seen in the brains of anthropoid Apes and Man.

The consideration of the size of the lobus hippocampi in the Cetacea is of especial interest, owing to the remarkably modified olfactory apparatus in those mammals. In the common Porpoise (*Phocæna communis*), in which the olfactory nerves are not developed, the lobus hippocampi is situated on the under and inner face of the hemisphere, and is continuous with the antero-inferior end of the gyrus hippocampi. The lobus in the specimen examined is 8 mm. in greatest breadth and 18 mm. in length, and the cornu Ammonis is fused with that surface, which is directed to the cavity of the descending horn.

The brain of the Narwhal (*Monodon monoceros*) is represented in fig. 3. It is a very characteristic Cetacean brain, and illustrates in an interesting way the antero-posterior compression of the hemispheres, and the great increase in transverse diameter, as compared with the brains of non-cetacean mammals. The brain of the Narwhal is also anosmatic, the lobus hippocampi (LH) is a distinct mass on the under surface of the hemisphere immediately behind the inner end of the deep Sylvian fossa. It is divided into an inner and an outer part by a fissure extending obliquely on its under surface. Its greatest breadth is 19 mm., and its antero-posterior diameter is 31 mm. Both the gyrus hippocampi and cornu Ammonis are prolonged into it. A non-convoluted area, 35 mm. in breadth and 27 mm. in antero-posterior diameter, is situated in front, and to the inner side of the Sylvian fossa and optic tract. It is the perforated or quadrilateral space (Q), the *area desert* of Broca, and no vestige

either of olfactory peduncle or roots can be seen in connection with it.[1]

FIG. 3.—Basal surface of the brain of the anosmatic Narwhal (*Monodon monoceros*).

In a *Balænoptera rostrata* (fig. 33), where the olfactory peduncle and roots are small and rudimentary in relation to the size of the hemisphere, the lobus hippocampi is 32 mm. long and 18 mm. broad: its dimensions in relation to the size of the hemisphere being practically the same as in the Narwhal. The quadrilateral perforated area (Q) is also distinct, and bounded anteriorly by the inner and outer roots of the olfactory peduncle. Its transverse and antero-posterior diameters are respectively 25 mm.

The Porpoise, in the general dimensions of its cerebrum, approxi-

[1] It is sometimes said that the reason why the Porpoise and other Delphinidæ have no olfactory organs is, because, from living in water, odorous particles would be so diffused and diluted that they could not excite the nerves of smell, which have accordingly atrophied and disappeared. But the Whalebone Whales, which have a similar habitat, have an olfactory apparatus, although it is small in relation to the size of the brain (fig. 33). Fish also have well-developed olfactory organs. The diffusion of odorous particles in an aqueous medium is not therefore a sufficient explanation of the disappearance of the smell apparatus in the Delphinidæ.

mates to that of the brain of the Elephant Seal, and the Walrus, animals in which the olfactory apparatus is of a size to include them in the group of microsmatic mammals, though their smell organs are more highly developed than in the human brain. In the Elephant Seal the lobus hippocampi is 19 mm. broad and 23 mm. long; in the Walrus the corresponding dimensions are 19 and 27 mm., so that it is considerably larger in them than in the Porpoise. The termination of the external root of the olfactory peduncle in the lobus hippocampi in macrosmatic and microsmatic mammals associates the lobus with the sense of smell, for which sense it is, as experiment has shown, one of the cerebral centres. The presence of a lobus hippocampi in anosmatic mammals, though it is relatively smaller in them than in osmatic mammals, leads one to infer that some additional function is to be associated with it.

As a rule, the lobus hippocampi is smooth on the surface, but it may in some brains be partially divided by shallow fissures. The presence of an oblique fissure has just been referred to in the Narwhal. In the Pig more than one short fissure extends in the long axis of the lobus; in the Ox a long fissure divides the lobus into an inner and an outer segment; one somewhat similar is seen in the Horse; whilst in the Polar Bear several curved furrows give its surface a convoluted appearance (figs. 3, 19, 26, 27).

The rhinal fissure separates the lobus externally, more or less perfectly, from the pallium, but the lobus also possesses a definite boundary, both internally and anteriorly.

The lobus is marked off internally by the *fissura hippocampi* (*h*), one of the fundamental fissures of the cerebrum (*grenz-furchen*). This fissure is visible on the inner and tentorial surface of the hemisphere, and forms at its lower end the inner limit of the lobus hippocampi. It curves upwards and forwards towards the splenium of the corpus callosum, but has not a constant mode of ending in that region. To take some examples: in the Pig, Ox, Horse, it ends below the splenium in the grey cortex of the convolution, which represents the upper end of the gyrus hippocampi; in many carnivorous animals it has a similar arrangement; in the Elephant Seal, Walrus, many Apes, and Man it turns round the splenium, and becomes continuous

with the callosal fissure which bounds the corpus callosum superiorly; in *Dasypus sexcinctus* it ends in the posterior part of the callosal convolution; in *Echidna* and *Macropus* it curves upwards on to the mesial surface above the rudimentary corpus callosum.

The lobus is bounded anteriorly by a depression, which is named the *Vallecula*, or *Sylvian fossa* (V). This fossa varies materially in depth. In all macrosmatic brains it is shallow, and in some of these, as in *Talpa, Erinaceus, Lepus, Hyrax*, it is very faintly marked. Whenever the olfactory peduncle and its external root are large, the fossa is crossed in the antero-posterior direction by this root in its passage backwards to join the lobus hippocampi. In microsmatic and anosmatic brains, on the other hand, the fossa is considerably deeper. Two factors come into play in contributing to its depth. The one is an absolute and relative diminution in the magnitude of the rhinencephalon, which is accompanied by a constriction of the olfactory peduncle, and an imperfect development of its roots, more especially of the external root. The other is an absolute and relative increase in the size of the pallium in the region around the Sylvian fossa, so that the pallium is elevated and projects beyond it.

The Vallecula, or Sylvian fossa, belongs, therefore, fundamentally to the Rhinencephalon; though, in the process of evolution of the higher and more complex mammalian brains, the enormous development of the pallium in its immediate neighbourhood contributes materially to its depth, and it becomes continuous in them with the Sylvian fissure.

Pallium.

In all mammals the pallium is larger than the rhinencephalon, though the size is not so great proportionally in the lower as in the higher mammals. The pallium is the part of the hemisphere which, in a large number of mammals, possesses a more or less complex arrangement of convolutions. In some orders, however, the surface of the pallium is not convoluted, but retains throughout life the smooth appearance which is the universal characteristic of the cerebral hemispheres at an early stage of development. Even in some orders, where the majority

of the species have convoluted brains, other species may retain the more primitive non-convoluted character. Mammals in whom the surface of the hemisphere is not convoluted are called smooth-brained, or Lissencephala.

The Insectivora are apparently the order in which the smooth-brained surface of the cerebral hemispheres is preserved throughout life most perfectly in all the genera.[1] I shall illustrate

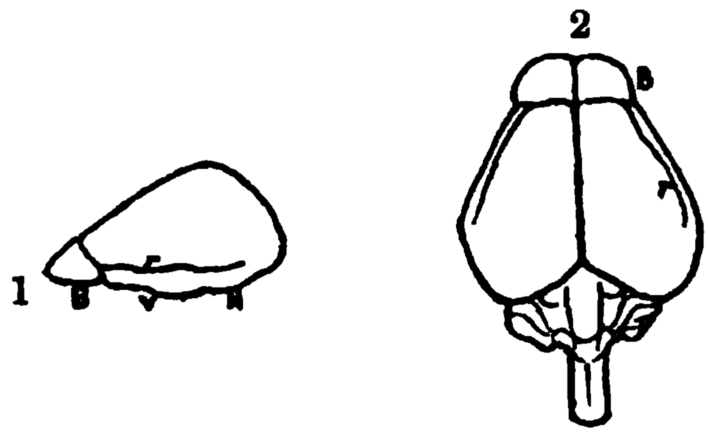


FIG. 4.—Brain of the Mole. 1, profile of hemisphere; 2, vertex view of brain.

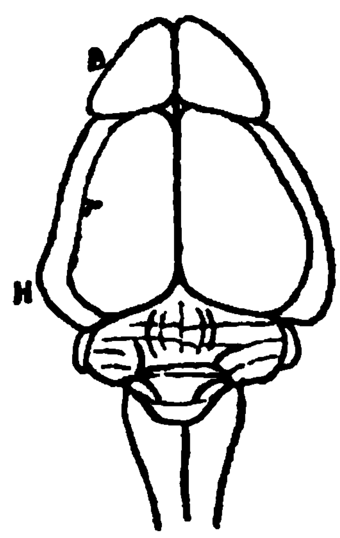


FIG. 5.—Vertex view of brain of Hedgehog.

the appearance of the brain with figures of the British species, *Erinaceus europæus* (fig. 5) and *Talpa europæa* (fig. 4). The Rodentia also are almost universally smooth-brained (fig. 1). But in some genera traces of shallow fissures may occasionally be seen on the surface, which indicate an early stage in the formation of convolutions. Leuret and Broca figure a short, shallow, antero-posterior fissure on the upper part of the hemisphere of the Beaver (*Castor fiber*), a little to the outer side of the mesial longitudinal fissure, and the latter also figures a corresponding fissure in the Marmot and Rabbit. Leuret depicts a similar fissure in the Agouti. Broca figures a short antero-posterior fissure on the mesial surface of the pallium above the corpus callosum in the Beaver, Marmot, and Rabbit, which he names the limbic (splenial) fissure.[2] In *Cœlogenys paca* the pallium exhibits additional shallow fissures, which give it a still more convoluted character.[3]

[1] Peters has described the brains of the Insectivorous genera *Solenodon*, *Rhynchocyon*, *Petrodromus*, and *Macroscelides*, in *Abh. der k. Akad. der Wiss.*, Berlin, 1863, and *Reise nach Mossambique*, 1852. A. H. Garrod has figured and described the brain of *Tupaia belangeri* in *Proc. Zool. Soc.*, 1879, and in Collected Scientific Papers.

[2] Rogner figures in *Zeitsch. f. Wiss. Zool.*, vol. 39, pl. xxxv. fig. 12, the brain of a Hare in which there is a splenial fissure.

[3] See Leuret, *Anat. Comp. du systéme nerveux*, pl. iii.

The Cheiroptera are usually regarded as smooth-brained mammals. This may probably be the case in the smallest Bats, but it does not apply to some of the larger species. Thus, in a Collared Fruit Bat (*Cynonycteris collaris*) a short sagittal fissure is situated in each hemisphere, a little external to the mesial longitudinal fissure, so as imperfectly to mark off a sagittal convolution forming the margin of the hemisphere. The sagittal fissure is better marked than in the brains of the Rabbit and Marmot. On the mesial surface of the same brain an antero-posterior fissure, corresponding to the limbic fissure of Broca—the splenial fissure of Krueg—divides the surface into callosal and marginal convolutions. The splenial fissure extends behind the splenial end of the corpus callosum on to the tentorial surface of the hemisphere, and differentiates the upper end of the gyrus hippocampi. In

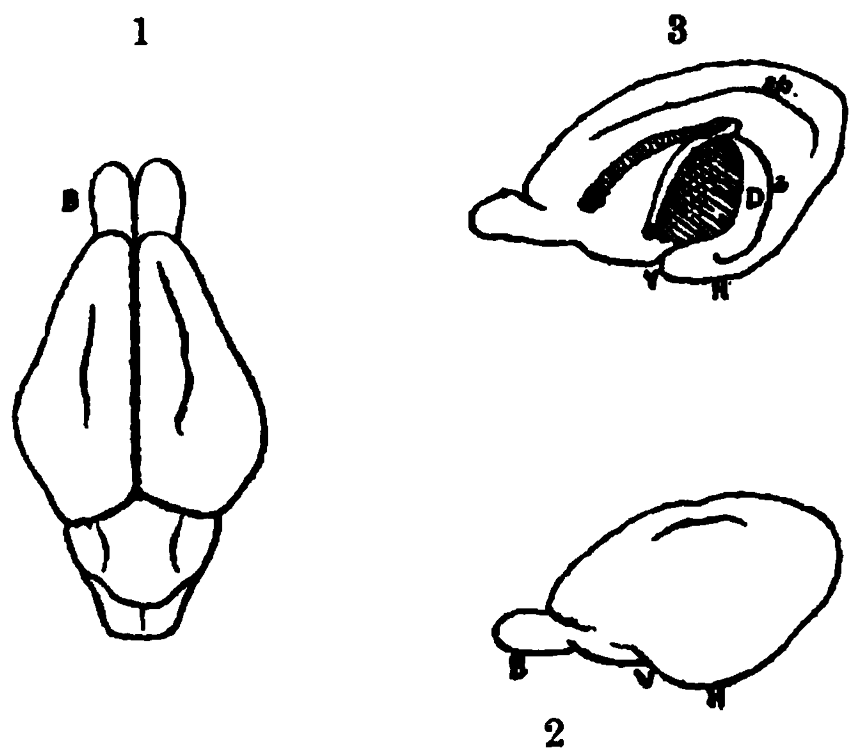


Fig. 6.—Brain of *Cynonycteris collaris*. 1, vertex view ; 2, cranial surface ; 3, mesial surface.

a *Pteropus medius* a fairly deep depression extends antero-posteriorly for nearly 4 mm. on the cranial surface about mid-

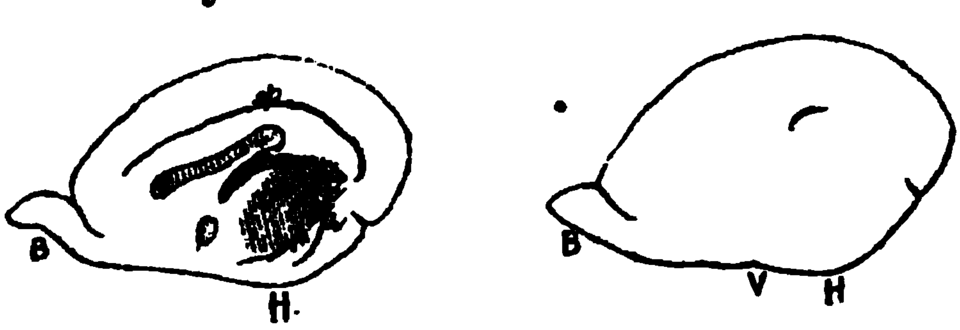


Fig. 7.—Hemisphere of *Pteropus medius*. 1, cranial aspect ; 2, mesial surface.

way between the mesial longitudinal fissure and the lobus hippocampi. On the mesial face of the hemisphere a very

distinct splenial fissure begins in front of the anterior end of the corpus callosum, and extends back to the tentorial surface, so that marginal, callosal and hippocampal gyri are all differentiated.

Other orders of mammals also contain species with both smooth and convoluted brains. Thus in the Monotremata *Ornithorhynchus* is smooth-brained. In each hemisphere the two fundamental limiting fissures (*grenz-furchen*), named rhinal (*r*) and hippocampal (*h*), which form the limits of the rhinencephalon, are present. In the concavity of the hippocampal fissure a distinct gyrus dentatus is situated. The surface of the pallium itself is, however, smooth, though I have seen it indented with shallow vascular furrows.

Echidna, on the other hand, has a convoluted brain. The species which I have examined is *E. hystrix*. The rhinencephalon with its fundamental limiting fissures (*r*, *h*) is distinct,

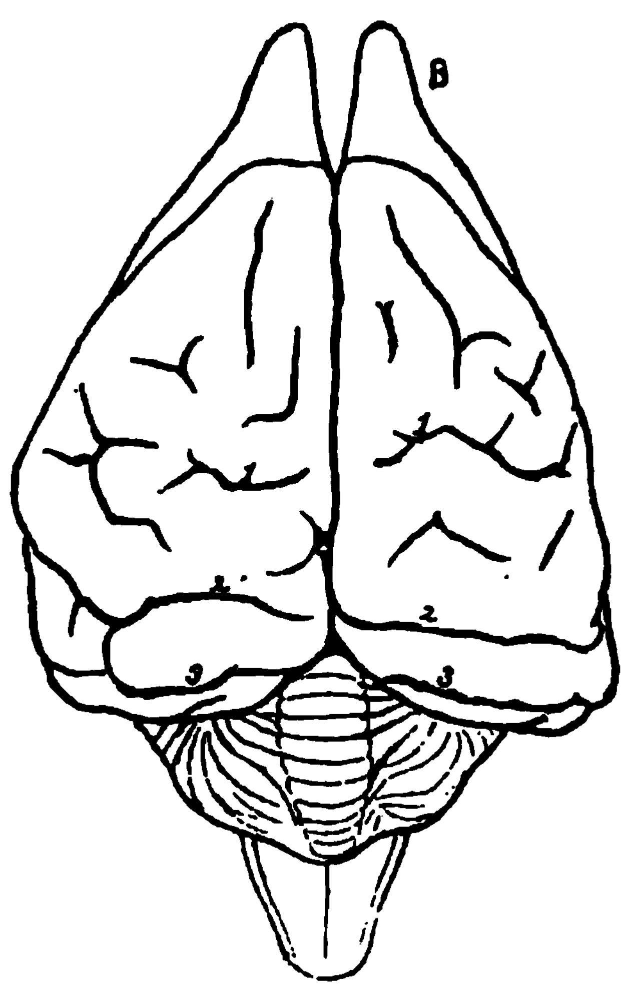


FIG. 8.—Vertex view of brain of *Echidna hystrix*.

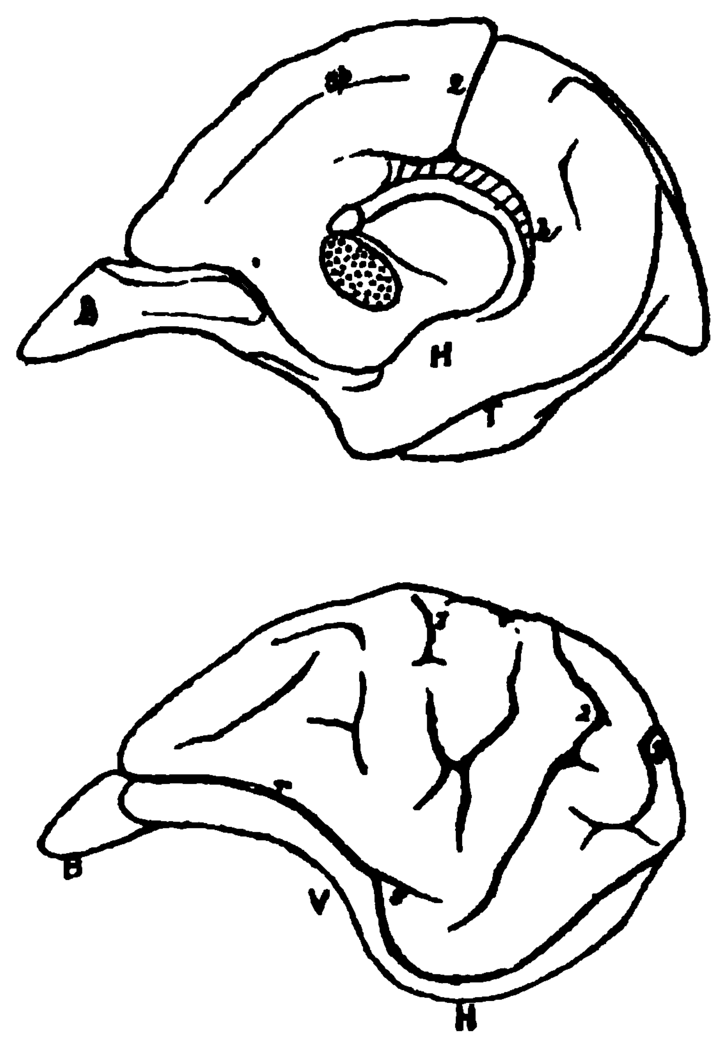


FIG. 9.—Hemisphere of *Echidna hystrix*. 1, cranial surface; 2, mesial surface.

and the gyrus dentatus is even more strongly denticulated than the corresponding structure in the human brain. The pallium is definitely convoluted, and measures 39 mm. in antero-posterior and 28 mm. in vertical diameter, but the fissures and convolutions on opposite sides are not symmetrical. Three fissures, 1, 2, 3,

extend more or less completely down its outer surface in the vertical transverse or coronal direction, almost from the mesial longitudinal to the rhinal fissure, so as to map out convolutions having a similar direction, and these fissures have short subordinate fissures proceeding from them. The surface of the pallium in front of the most anterior vertical transverse fissure, No. 1, forms the anterior half of the pallium, and is divided by short antero-posterior fissures into small convolutions, the most posterior of which bounds No. 1 anteriorly. Vertical transverse fissure No. 2 in the right hemisphere turns round its upper margin, and becomes continuous with the fissura hippocampi. The vertical transverse convolution between the fissures Nos. 1 and 2 is partially divided into anterior and posterior limbs by subordinate fissures. A small fissure, marked *s* in fig. 9, may perhaps represent the Sylvian fissure. The mesial surface of the hemisphere possesses an antero-posterior fissure, which, although the corpus callosum is rudimentary, should be regarded as a splenial fissure. It divides this surface into two longitudinal convolutions, which are homologous with the callosal and marginal convolutions in the higher brains.

The Marsupialia also are in part smooth-brained and in part convoluted. In *Phalangista vulpina* rhinal and hippocampal fissures differentiate the rhinencephalon, and a shallow Sylvian fossa bounds the lobus hippocampi anteriorly. The cranial surface of the pallium is smooth, though two slight indentations at the margin of the hemisphere mark the beginning of two fissures,

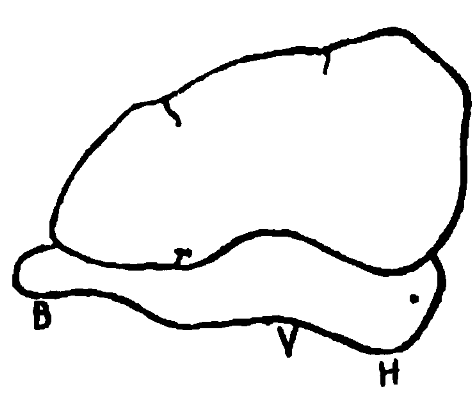


FIG. 10.—Cranial surface of brain of *Phalangista vulpina*.

which traverse in the vertical transverse direction the mesial surface of the hemisphere. The more posterior of these two fissures extends to the tentorial surface of the hemisphere, and partially differentiates a gyrus hippocampi behind the hippocampal fissure, whilst in front of the last-named fissure is a

distinct gyrus dentatus. A faint indication of a splenial fissure is above the rudimentary corpus callosum.

Dasyurus ursinus has also a distinct rhinencephalon, and the cranial surface of the pallium is smooth, though, as in *Phalangista*, also marked by shallow vascular furrows.[1] In *Halmaturus ruficollis* the limiting fissures of the rhinencephalon are distinct. The cranial surface of the pallium is traversed by three vertical transverse fissures, which radiate upwards from the rhinal fissure, and give a convoluted character to the surface.

In *Macropus major* the pallium is distinctly separated from the rhinencephalon. The cranial surface of the pallium is

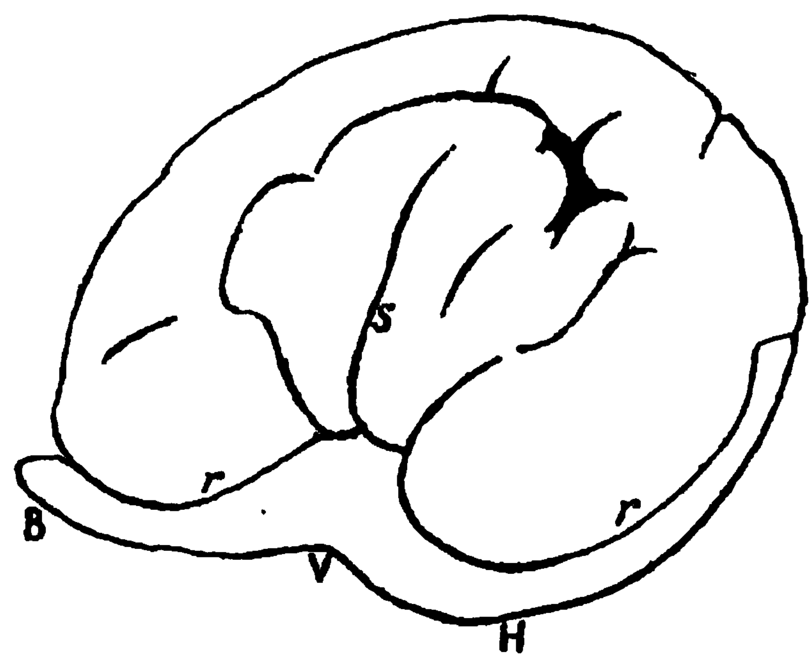


FIG. 11.—Cranial surface of hemisphere of *Macropus major*.

traversed by three fissures radiating upwards in the vertical transverse direction, and starting from the rhinal fissure immediately opposite the Sylvian fossa. The most anterior

[1] Sir Richard Owen has described and figured (*Phil. Trans.*, 1837) the brains of *Phascolomys wombatus*, *Macropus major*, *Dasyurus ursinus*, and *Didelphys virginiana*. The brain of Macropus closely resembles that figured above from a specimen in the Oxford University Museum. The Wombat is apparently more feebly convoluted, and the Opossum is smooth-brained. M. Gervais figures (*Nouvelles Archives du Muséum*, 1869) the brains of *Macropus giganteus* and the casts of the cranial cavity of a number of other marsupials. Figures of the Wombat, Kangaroo, and Thylacine are also given by Mr Flower in the *Phil. Trans.*, 1865. Mr W. A. Forbes figures and describes the brain of the Koala (*Phascolarctos cinereus*) in *Proc. Zool. Soc.*, 1881, and in Collected Scientific Papers, p. 183. The pallium is smooth, and is separated from the rhinencephalon by a rhinal fissure. The lobus hippocampi has a well-marked fossa Sylvii for its anterior boundary. A slight indentation in the pallium opposite the Sylvian fossa probably represents a rudimentary Sylvian fissure. The fissura hippocampi is distinct and prolonged on to the mesial face of the hemisphere above the small corpus callosum, and behind it is an *f*-shaped sulcus which reaches the upper and lower margin of the hemisphere.

radiating fissure is continued into an arcuate fissure which arches backwards above the middle radiating fissure, and almost reaches the posterior radiating fissure. The middle radiating fissure is apparently a Sylvian fissure (which is probably also the case with the corresponding fissure in *Halmaturus*). The convolution between it and the arcuate fissure is the convolution of the Sylvian fissure, and that between the arcuate fissure and the median longitudinal fissure is a marginal convolution. Behind the posterior radiating fissure a short vertical transverse fissure, not reaching the rhinal fissure, divides the part of pallium lying immediately above the lobus hippocampi into two convolutions.[1] The mesial surface, in addition to the fissura hippocampi, possesses a splenial fissure and callosal and marginal convolutions. The brain of a smaller species of *Macropus* in the University Museum[2] has only two fissures radiating from a spot in the rhinal fissure opposite the Sylvian fossa; the more posterior reaches the hinder end of the cerebrum, and is almost continuous with a fissure on the tentorial surface, which imperfectly differentiates the posterior boundary of a

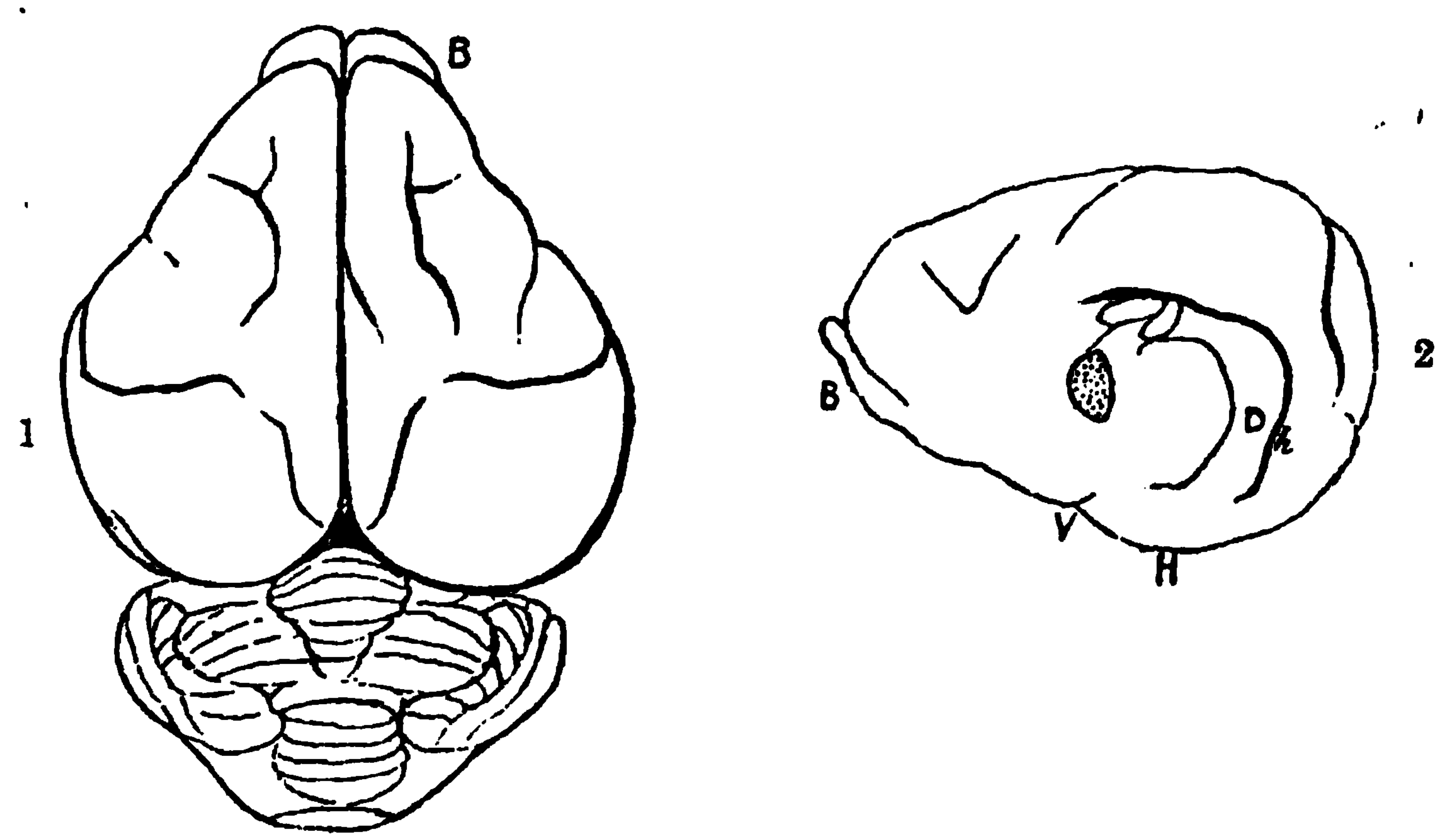


FIG. 12.—1, Vertex view of brain of a Macropus ; 2, mesial surface.

gyrus hippocampi situated behind the hippocampal fissure. A fissure, which may be called genual, is present on the anterior part of the mesial surface in front of and above the rudimentary corpus callosum (fig 12).

[1] This fissure has unfortunately been omitted by the draughtsman in figure 11.
[2] It is labelled "Bush Kangaroo."

The Edentata possess convoluted brains. The species which I have dissected are *Dasypus sexcintus* and *Cholœpus*

Fig. 13.—Brain of *Dasypus sexcintus.* 1, vertex view; 2, cranial surface; 3, mesial surface; 4, vertical transverse section.

hoffmanni.[1] In *Dasypus*[2] an antero-posterior fissure traverses

[1] Tiedemann has figured the brain of *Bradypus didactylus* (*Icones Cerebri Simiarum*, &c.); Rapp has described *D. novemcinctus*; W. H. Flower has figured *Cholœpus didactylus* (*Phil. Trans.*, 1865), Paul Gervais has figured (*Nouvelles Archives du Museum*, v., 1869) the brains of *Euphractus* (*Dasypus*) *villosus*, *Manis temmincki*, *Myrmecophaga jubata*, *Orycteropus capensis*; Georges Pouchet (*Journal de l'Anat. and Phys.*, vols. v. vi., n.s., 1868, 1869) has figured the brains of Dionyx, Pangolin, and Bradypus; W. A. Forbes has figured the brain of *Myrmecophaga jubata* (*Proc. Zool. Soc.*, 1882, and in Collected Scientific Papers). In all these Edentates, except Dionyx, the pallium is convoluted, although the convolutions are more numerous in Myrmecophaga and Manis than in Dasypus. In Manis there is apparently, from Gervais's figure, a well-marked Sylvian fissure, and the fissure depicted by Forbes, *l.s.s.*, fig. 3, in Myrmecophaga is doubtless also the fissure of Sylvius.

[2] Fig. 13 is reproduced from my paper on the brain of *Dasypus sexcinctus* in *Jour. Anat. and Phys.*, vol. i. p. 314, 1867.

almost the whole length of the pallium, and turns round the posterior end of the hemisphere to become continuous with the hippocampal fissure. Two longitudinal convolutions are thus differentiated,—the one between this fissure and the interrupted rhinal fissure, the other between this fissure and the mesial longitudinal fissure,—and this latter convolution has a subordinate fissure in it. A short splenial fissure on the mesial surface marks off a marginal from a callosal convolution. In *Cholœpus*, near the anterior end of the pallium, a vertical transverse fissure extends upwards from the rhinal fissure, and turns round the upper margin of the hemisphere to the mesial surface; it marks off the anterior end of the pallium as a distinct convolution (fig. 14). Behind this fissure a longitudinal fissure extends backwards, which separates a marginal sagittal convolution bounding the mesial longitudinal fissure from a second longitudinal convolution situated lower down on the cranial surface of the pallium. Below this again is an arched fissure, which forms the upper limit of a third convolution, the lower boundary of which is the rhinal fissure. There is no definite Sylvian fissure, but a faint indentation in the lower border of the

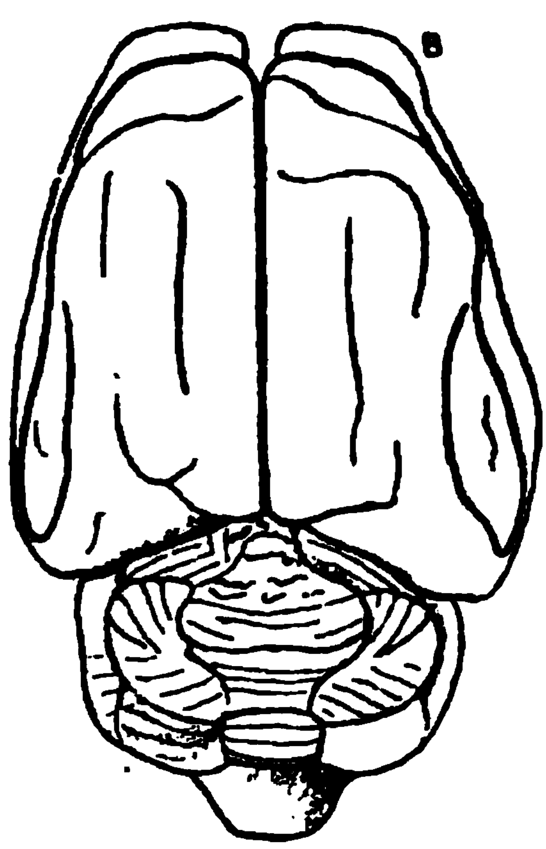


FIG. 14.—Vertex view of brain of *Cholœpus hoffmanni.*

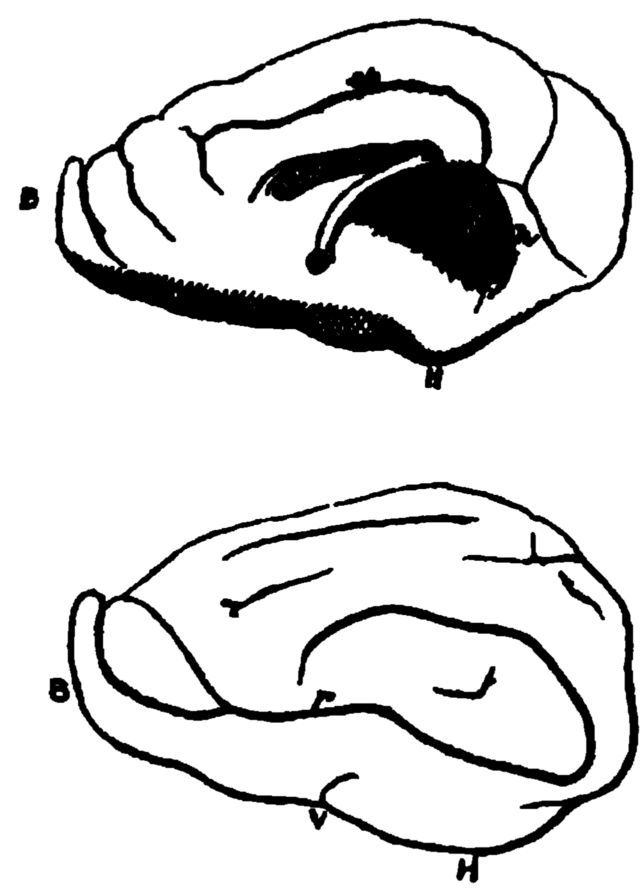


FIG. 15.—1, cranial surface; 2, mesial surface of hemisphere of *Cholœpus hoffmanni.*

pallium, a little above the Sylvian fossa, may possibly be its representative. On the mesial surface of the pallium a splenial

fissure commences in front of the corpus callosum. It extends backwards to behind the splenium, and apparently becomes continuous with the hippocampal fissure. The convolution which forms the posterior boundary of the hippocampal fissure is bounded behind by a deep fissure, which below almost joins the posterior end of the rhinal fissure, whilst above it turns on to the cranial surface of the pallium and ends in the second longitudinal convolution, which it assists in partially dividing into an upper and a lower tier (fig. 15).

In *Hyrax*, also, the brain is convoluted. In *H. capensis* the cranial surface of the pallium is divided into tiers of longitudinal convolutions by antero-posterior fissures. The highest convolution is slender and almost equal in length to the hemisphere, and forms the margin (*m*) of the mesial longitudinal fissure.

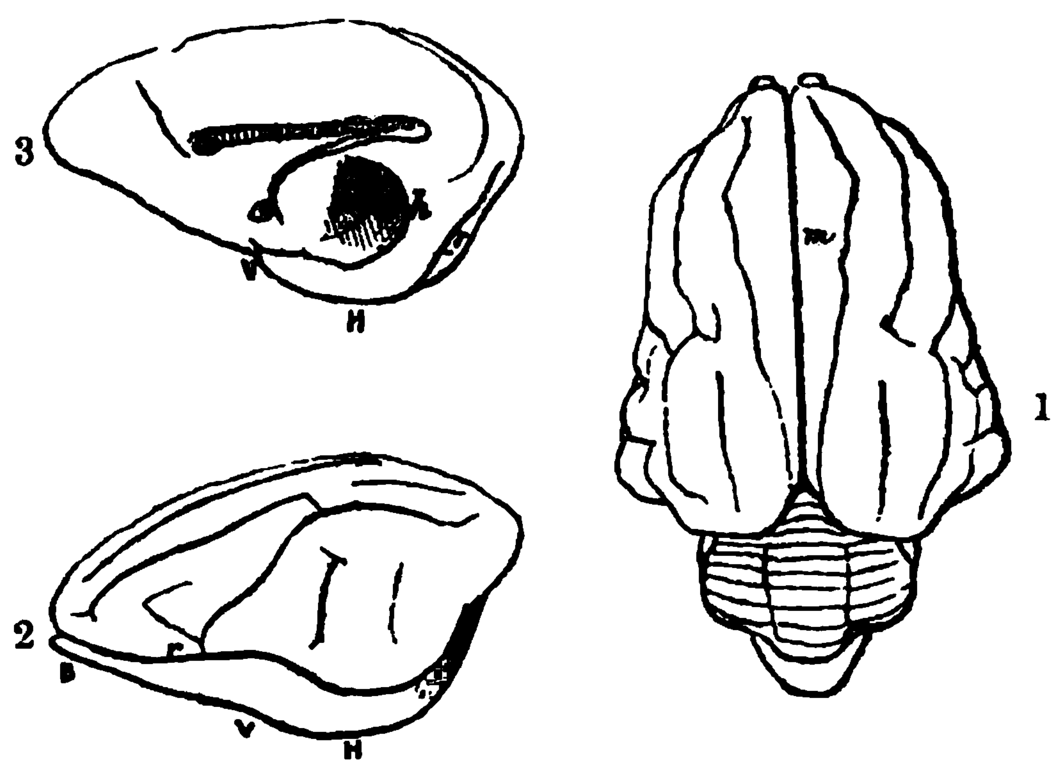


FIG. 16.—Brain of *Hyrax capensis*. 1, vertex view; 2, cranial surface; 3, mesial surface.

The fissure which forms its lower boundary extends so far back as to end on the tentorial surface of the hemisphere. The second longitudinal convolution is equal in length to the hemisphere, and is partially divided into an upper and a lower tier by an interrupted antero-posterior fissure. The fissure, which bounds the second convolution below, begins a little in front of the Sylvian fossa, and extends upwards and backwards almost to the hinder end of the hemisphere. Between this fissure and the rhinal is a relatively broad portion of the pallium, which is divided by two short vertical transverse fissures into three small vertical convolutions. The more anterior of these fissures has in

some respects the position and direction of a Sylvian fissure, but it scarcely reaches the rhinal fissure. The mesial surface of the hemisphere does not possess a splenial fissure, so that a callosal convolution is not demarcated from the marginal convolution; but a short vertical transverse fissure, which perhaps represents the *genual fissure* of Krueg, as seen in some of the Ungulata, is situated a little in front of the genu of the corpus callosum.

Before I pass to the consideration of the convolutions in those orders in which the pallium is elaborately convoluted, it may be of interest briefly to review the fissures and convolutions in the mammals just described, with the view of noting their order of relative appearance.

The importance of the rhinal and hippocampal fissures as fundamental limiting fissures for the rhinencephalon has already been referred to. But the fissura hippocampi (*h*) is also the limiting fissure for the gyrus dentatus (D), which is thus a fundamental gyrus, and is present in all mammals. Although in the brains of mammals so far apart as *Echidna* and *Homo*, the grey matter of this gyrus has the denticulated appearance which has led to its special descriptive name, yet in most mammals it is smooth on the surface. The gyrus dentatus varies in breadth. In the human brain it is a narrow stripe, and lies at the bottom of the hippocampal fissure, so that it is not easily seen until the tænia hippocampi is drawn on one side. In Mammalia, generally, it forms a distinct band visible on the surface. In the small brain of the Hedgehog (*Erinaceus*) it is 3 mm. broad, and in the very much larger brain of the Horse it is 6 mm. broad, so that it does not increase in size in the same ratio as the pallium. It is precisely bounded in front by the so-called transverse fissure of the cerebrum, through which the choroid plexus of the pia mater is projected towards the descending horn of the lateral ventricle. At its lower end it is fused with the lobus hippocampi of the rhinencephalon, and it is in relation with the projection into the descending horn called hippocampus major or cornu Ammonis.

Another fissure, which appears low down in the mammalian brain, is that which extends on the upper part of the cranial surface in the longitudinal or sagittal direction, parallel to the mesial longitudinal fissure; it marks off a convolution which

may be called sagittal or marginal (*m*), for it forms the margin of the great mesial fissure. This fissure is, as previously stated, occasionally present in the brains of rodents and bats, and appears indeed in the pallium of these and some other mammals before there is any definite evidence of a Sylvian fissure.

In the study of the Sylvian fissure care should be taken to discriminate between it and the Sylvian fossa or vallecula. As already pointed out, the Sylvian fossa (v) is a depression in the rhinencephalon immediately in front of the lobus hippocampi, and it is seen as low down as the brains of the monotremes. The Sylvian fissure, on the other hand, belongs to the pallium. It is not seen in the smooth-brained *Ornithorhynchus*, or in the lissencephalous rodents, insectivores, or bats. In *Echidna*, again, the small fissure, marked *s* in fig. 9, may perhaps represent a Sylvian fissure. In *Macropus major* I think it is possible that the middle vertical transverse fissure is a Sylvian fissure. The radiating character of these fissures in the brains of *Macropus* and *Halmaturus*, in which it must be remembered the corpus callosum is rudimentary, is of interest in connection with the radiated arrangement of the transitory fissures on the cranial surface of the human brain at an early stage of development.[1] In *Hyrax* the more anterior vertical transverse fissure is also perhaps to be regarded as representing a Sylvian fissure, though it does not reach the rhinal fissure. It would appear, therefore, that in the evolution of the brain in the mammalian series the Sylvian fissure may be present in the brains of such low mammals as *Echidna* and *Macropus*, which are also convoluted, whilst it is absent in the smooth-brained rodents, bats, and insectivores—mammals that in other respects are more highly organised than the monotremes and marsupials. Further, in these lissencephala there is a tendency for a sagittal fissure and a marginal convolution to differentiate on the cranial surface before there is any evidence of a Sylvian fissure being present.

But the mesial surface of the hemisphere is also of interest in connection with the appearance in it of fissures and convolutions.

[1] See an interesting discussion on these "complete" fissures in the human brain by Professor D. J. Cunningham in *Journal of Anatomy and Physiology*, April 1890.

The fundamental character of the fissura hippocampi and gyrus dentatus has already been pointed out, and in the brains of *Ornithorhynchus* and the *Insectivora* they are apparently the only parts which are morphologically differentiated. In some rodents, however, traces appear of a longitudinal fissure situated in the grey cortex above the corpus callosum, which is more accentuated in the bats *Cynonycteris* and *Pteropus*. It is named sometimes the splenial, at others the limbic, fissure (*sp*). This fissure is seen also in *Echidna*, in Marsupialia, in *Dasypus* and *Cholæpus*; and when it exists it differentiates a callosal from a marginal convolution. Moreover, when it is prolonged backwards and downwards to the tentorial surface of the pallium, it differentiates the posterior limit of a gyrus hippocampi. In the smooth-brained mammals, in which it is present, it is differentiated before a Sylvian fissure appears in them. In *Hyrax*, although the cranial surface is well convoluted, and a genual fissure is present in front of the corpus callosum, yet the splenial fissure, properly so called, is not differentiated. In these lower mammals, therefore, it would seem that the relative order in which the fissures make their appearance is not rigidly fixed, but that it varies in the different species.

From the description already given, it will have been seen that the fissures and convolutions are not uniform in their direction and arrangement, but that three leading groups, which may be described as sagittal or longitudinal, vertical transverse or coronal, and arcuate, may be recognised. The sagittal or longitudinal group lie parallel to the mesial longitudinal fissure; the vertical transverse lie on the surface of the pallium, and are directed from the mesial longitudinal fissure towards the rhinal fissure; and the arcuate group pursue a curved course from before backwards. All these groups assume more strongly marked characters in the more highly convoluted brains.

The orders in which the pallium assumes the most complex arrangement of convolutions are the Proboscidea,[1] Ungulata,

[1] Mayer (*Nova Acta*, vol. xxxii.) has given a figure of the brain of the Indian Elephant; Leuret also has figured the convolutions. Krueg has figured that of the African Elephant (*Zeitsch. f. wiss. Zool.*, vol. 33, pl. xxxviii.). In the Museum of the Royal College of Surgeons, England, is a beautiful specimen, which has not, I believe, been described.

Cetacea, Carnivora, Pinnipedia, and Primates with Homo.[1] But even in some of these orders there are a few species in which the pallium is either smooth or only feebly convoluted. This is especially the case in the smaller species of these orders, where the weight of the body is small, but where the brain is relatively larger to the body than is the case in the larger species of the same order. A central sensori-motor apparatus of sufficient magnitude for the requirements of the animal can thus be accommodated in a cortex possessing a plane surface, and the need for a convoluted folding of that surface does not arise. The most striking examples of smooth-brained mammals, in an order otherwise gyrencephalous,[2] is seen in the little Marmoset Monkey (fig. 36),[3] a genus of Primates.

To describe in detail the arrangement of the convolutions in gyrencephalous mammals would occupy much more time than is at my disposal, so that I shall limit myself to directing attention to the more striking general features in the plan of construction.

Convolutions and fissures extending in a direction which may be termed antero-posterior, sagittal, or longitudinal are to be seen. Invariably, I think I may say, the margin of the mesial longitudinal fissure, for either the whole or a considerable part of its length, is bounded by such a convolution, which is partly situated on the cranial and partly on the mesial surface of the pallium, and which is appropriately called marginal (*m*). In Man and the more highly convoluted Apes tiers of antero-posterior convolutions, with their intermediate fissures, make up a large portion of the frontal lobe.

[1] Comparatively little is known of the brain in the Sirenia. Dr Murie, in his well-known Memoir on the Manatee, figures the cerebrum as possessing both a rhinencephalon and a pallium. The pallium has a deep Sylvian fissure, and the cortex is marked by shallow fissures indicative of convolutions. The specimen was not in good order (*Trans. Zool. Soc.*, vol. viii.). Mr A. H. Garrod examined the brain of a Manatee twenty-four hours after death. He describes a Sylvian fissure, a hippocampal fissure, and a calloso-marginal (splenial) sulcus with indications of a superior frontal sulcus. He states that the brain does not present convolutions properly so called (*Trans. Zool. Soc.*, vol. x.).

[2] This term, as well as the term lissencephala in other parts of the text, is used only in its descriptive sense, and not as a taxonomic expression.

[3] Owen says that the weight of the midas Marmoset is to its body as 1 to 20; that of the Gorilla as 1 to 200.

The Sylvian fissure, common to all the gyrencephala, may, I think, be regarded as fundamentally vertical transverse in direction, though in some brains, especially in Man and the higher Apes, it is directed very obliquely backwards. Its length varies materially from a few mm., as in the smaller Carnivora and Ungulata, to several centimetres, as in Homo. Its depth also is variable, and in such brains as the Cetacea, Apes, and Man, where its depth is considerable, it more or less perfectly conceals a set of convolutions which constitute the insula or island of Reil.

In the Carnivora, Pinnipedia, Cetacea, and Ungulata certain convolutions and fissures are arranged in successive tiers in front of, above, and behind the Sylvian fissure, so as to assume a decidedly arcuate character. In the Carnivora they have been carefully studied in a large number of genera by many anatomists.[1] The most simple arrangement is to be seen in the smallest Carnivora, as the Ferret (*Mustela furo*) (fig. 17) and the domestic Cat (fig. 18), in which three simple convolutions arch above the Sylvian fissure, which may be named *Sylvian*, *supra-sylvian*, and *marginal*, whilst the intermediate arcuate fissures are *supra-sylvian* and *lateral*. The marginal convolution has more of an antero-posterior direction, and forms the longitudinal marginal convolution of the mesial longitudinal fissure. In the larger Carnivora, like the Tiger

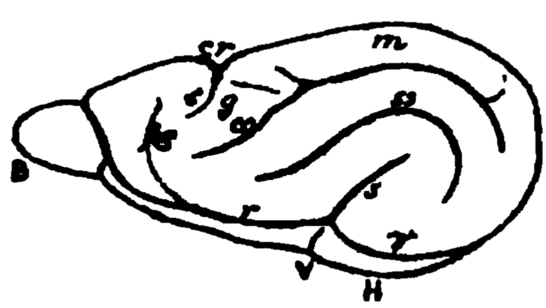


FIG. 17.—Cranial surface of hemisphere of *Mustela furo*.

and Polar Bear (fig. 19), similar tiers are also to be seen; the convolutions also are not so simple, but more winding and more frequently subdivided by secondary fissures. In the Canidæ (fig. 20), four tiers of convolutions are met with, which

[1] I may especially refer to the writings of Owen, Leuret, Flower, Benedikt, Pansch, and Krueg; also to my chapter on the Convolutions of the Brain in *Challenger Reports*, "Zoology," part lxviii., reprinted in *Journal of Anatomy and Physiology*, vol. xxii., 1888.

may be termed Sylvian, supra-sylvian, lateral, and sagittal or marginal, whilst the additional fissure may be named *medio-*

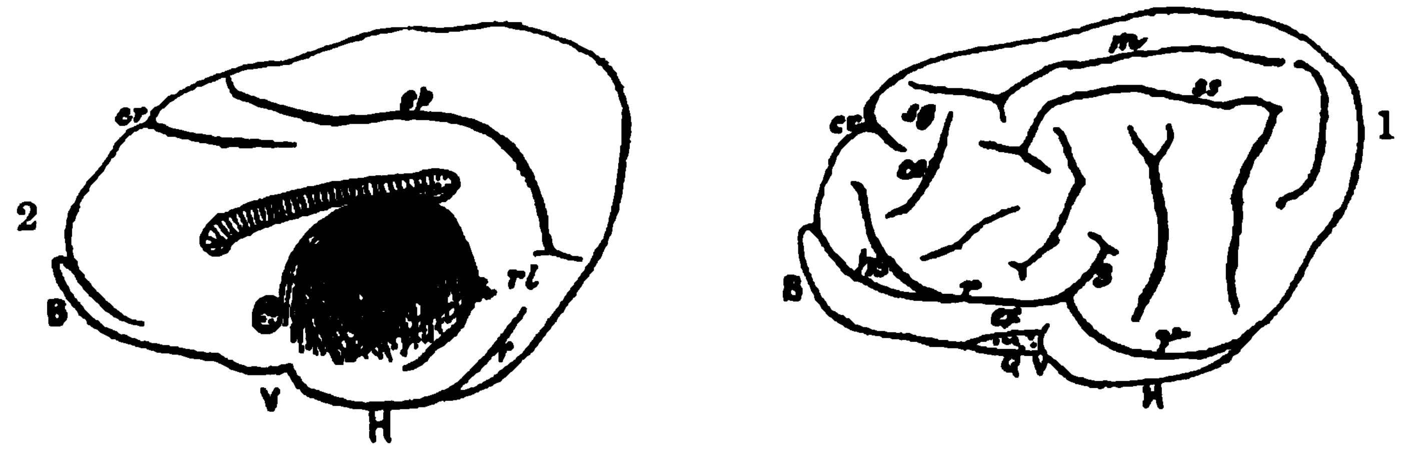


FIG. 18.—Hemisphere of *Felis domestica.* 1, cranial surface; 2, mesial surface.

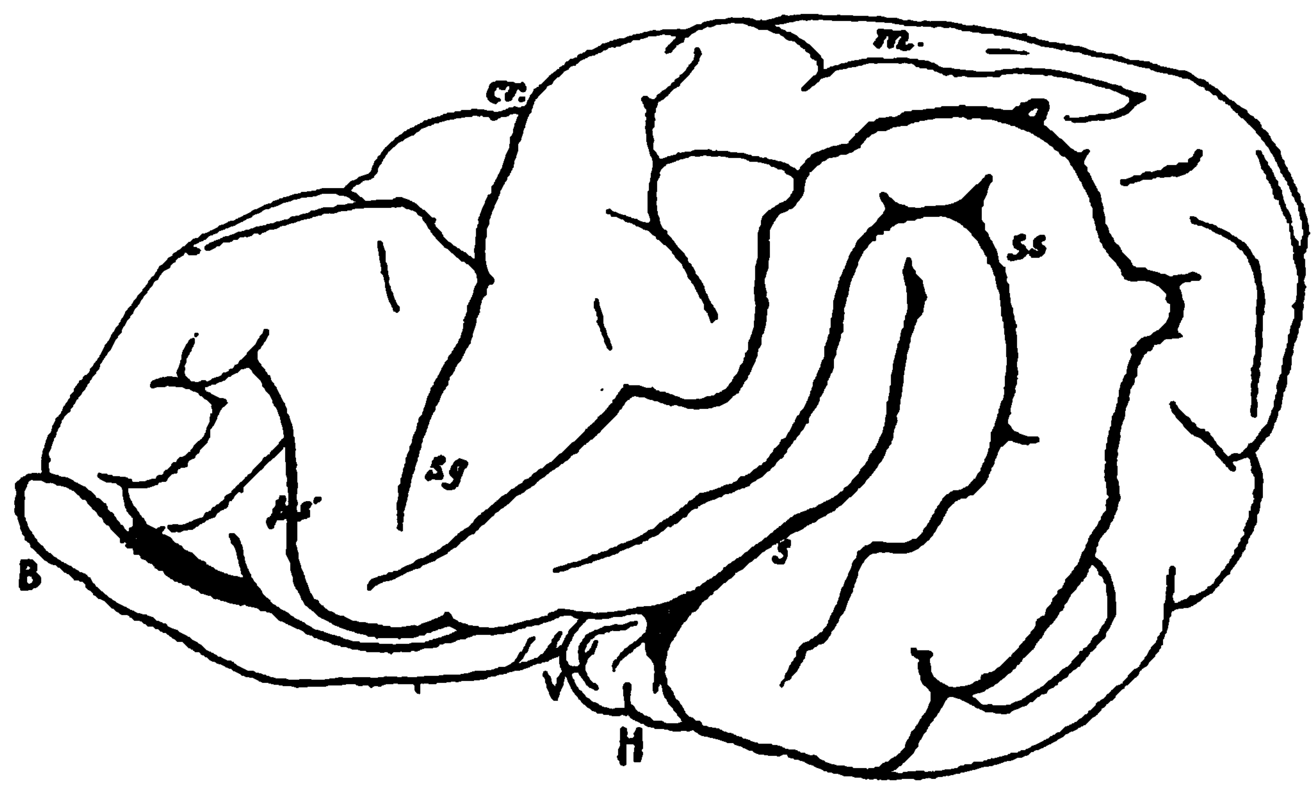


FIG. 19.—Cranial surface of the hemisphere of *Ursus maritimus.*

lateral. In the Pinnipedia four tiers of convolutions are also present, and their tortuosity is more marked than in the proper Carnivora (fig. 21). Both in the Elephant Seal and Walrus, the Sylvian convolution is partially sunk into the Sylvian fissure, and I have seen a similar arrangement in the brains of the Otter (*Lutra vulgaris*) and the Badger (*Meles taxus*).

In the Carnivora and Pinnipedia special names are applied to certain of the fissures on the cranial surface. A fissure, which springs from the neighbourhood of the Sylvian fossa or the rhinal fissure in front of that fossa, and which runs forwards and upwards on the cranial surface of the more anterior part of the pallium, is called the *præ-sylvian fissure* (*p.s.*). Owen gave the name *coronal fissure* (*co.*) to a fissure which passes more or less in the coronal direction down the cranial surface of the anterior part of the pallium. The coronal fissure may,

as in the Dog, or it may not, as in the Cat, be continuous with the lateral fissure, *i.e.*, the most superior of the arcuate

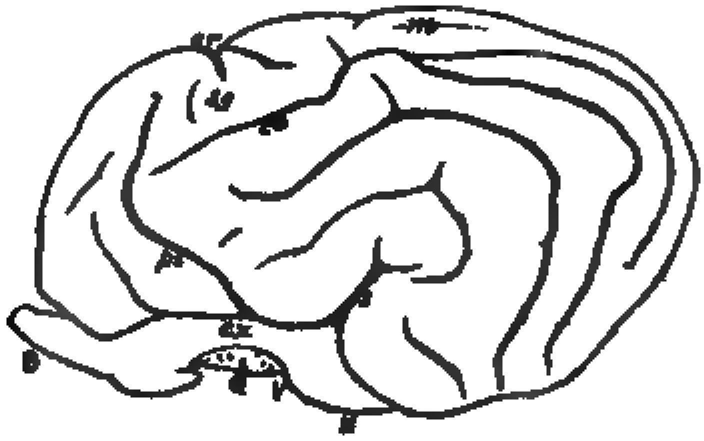


FIG. 20.—Cranial surface of hemisphere of *Canis familiaris.*

fissures of the pallium. The name of *coronal convolution* is sometimes given to the more anterior part of the second external convolution which bounds the coronal fissure posteriorly. The part of the supra-sylvian fissure which lies behind the Sylvian convolution is sometimes named *fissura supra-*

FIG. 21.—Cranial surface of the brain of *Trichechus rosmarus.*

sylvia posterior (*ssp*). In the carnivorous brain another vertical transverse fissure, the *crucial fissure* (*cr*) of Leuret,

is very characteristic. It extends from the mesial longitudinal fissure almost transversely outwards and is bounded by the *sigmoid gyrus* (*sg*) of Flower. The crucial fissure and sigmoid gyrus vary in their position antero-posteriorly. In the Walrus and Seals they are at the anterior end of the pallium; in the Cat in about the anterior fourth, in the Dog and Mustela at nearly the junction of the anterior and middle third, in the Bears at nearly the junction of the anterior and posterior half. The sigmoid gyrus separates the crucial and coronal fissures from each other. The most anterior end of the pallium, in such Carnivora as the Dog, has a beak-like form, and has been named the *prorean convolution;* whilst the fissure which forms its posterior boundary, situated in front of and almost parallel to the præ-sylvian fissure, is the *prorean fissure* of Krueg.

The mesial surface of the carnivorous brain has a distinct *splenial fissure,* which has a longitudinal and arcuate arrange-

FIG. 22.—Mesial surface of left hemisphere of *Macrorhinus leoninus.*

ment (figs. 18, 19). It differentiates the marginal from the callosal convolution, and as the callosal is continued behind into the hippocampal convolution, these two form the great arcuate gyrus fornicatus. A fissure bent downwards in front of the

genu of the corpus callosum is sometimes continued back into the splenial fissure, but at other times is independent of it, in the latter case it is named the *genual fissure* (*g*). In the Elephant Seal (*Macrorhinus*) the pallium above the splenial fissure is divided by a *supra-splenial fissure* into two tiers

quently prolonged into the most posterior part of the rhinal fissure (fig. 24). In the Carnivora generally these fissures are

FIG. 24.—Mesial surface of right hemisphere of *Canis familiaris.*

most usually separated from each other by a convolution which Broca has named retrolimbic (fig. 18, *rl.*)

The orbital surface of the pallium in the Carnivora possesses a distinct *olfactory fissure*, which is concealed by the bulb of the rhinencephalon; between it and the mesial longitudinal fissure is a *gyrus rectus*. In the Elephant Seal (fig. 2) and Walrus the olfactory fissure and gyrus rectus are also present. External to the olfactory peduncle is an *intra-orbital fissure* (*io*); between it and the olfactory fissure is an *internal supra-orbital gyrus* (*isc*), and between it and the præ-sylvian fissure is an *external supra-orbital gyrus* (*esc*).

In the brains of the Ungulata the cranial surface of the

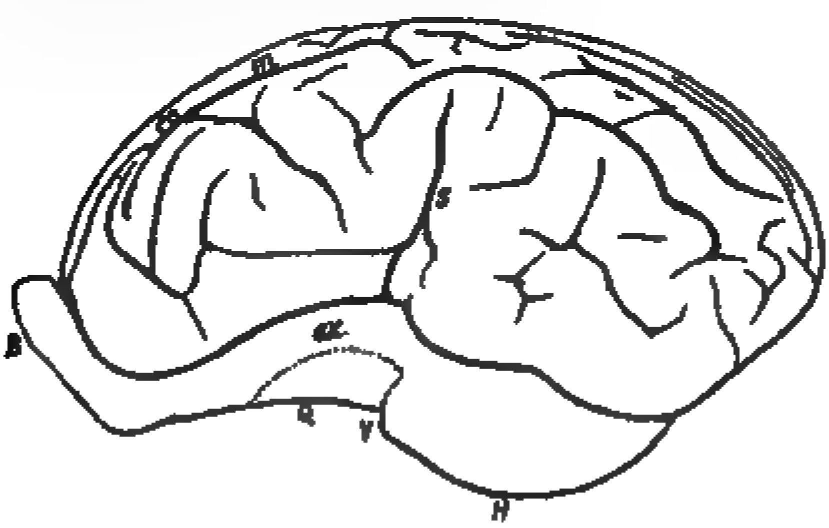


FIG. 25.—Cranial surface of hemisphere of *Ovis aries* (Sheep).

pallium shows a Sylvian fissure surmounted by tiers of arcuate fissures and convolutions. The laborious researches of Krueg,[1]

[1] *Zeitsch. f. wissen. Zoologie*, vol. xxxi. 1878.

have demonstrated the presence of at least three tiers of convolutions in a large number of species. The highest tier forms the marginal convolution of the mesial longitudinal fissure. This arrangement is seen in the Sheep (*Ovis aries*) (fig. 25). In some species, as the Ox and Horse, four tiers of convolutions, with

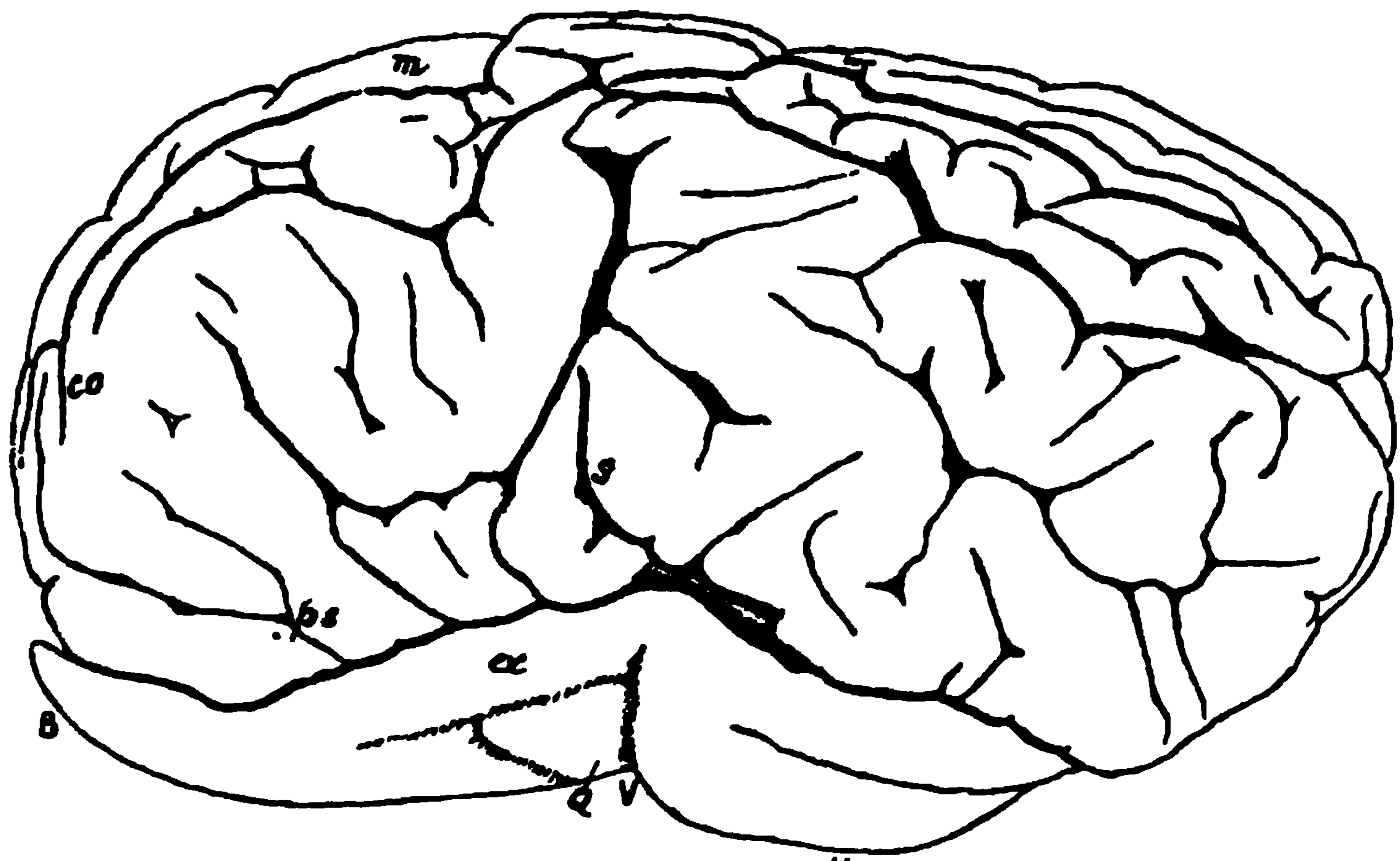


Fig. 26.—Cranial surface of hemisphere of *Bos taurus* (Ox).

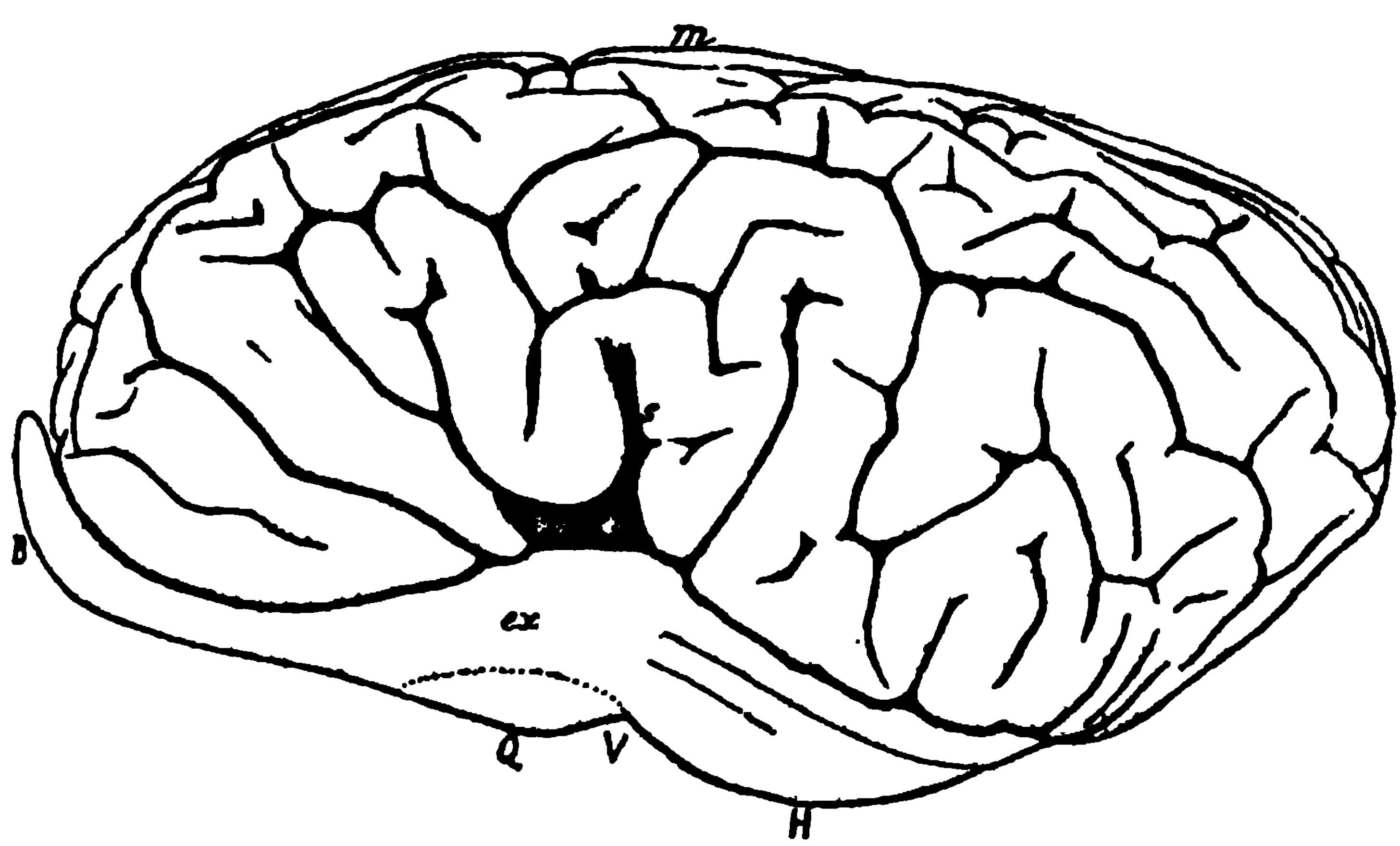


Fig. 27.—Cranial surface of hemisphere of *Equus caballus* (Horse).

corresponding fissures, are present, which may be named in terms similar to those employed in the nomenclature of the Dog's brain. Both coronal and præ-sylvian fissures exist in the ungulate brain. Some anatomists hold that a crucial fissure may

also be recognised. In the Suidæ, more especially in *Dicotyles*, a fissure runs transversely outwards from the mesial longitudinal fissure; at first sight it might be taken for a crucial fissure, but on closer observation it will be seen to join the coronal fissure,

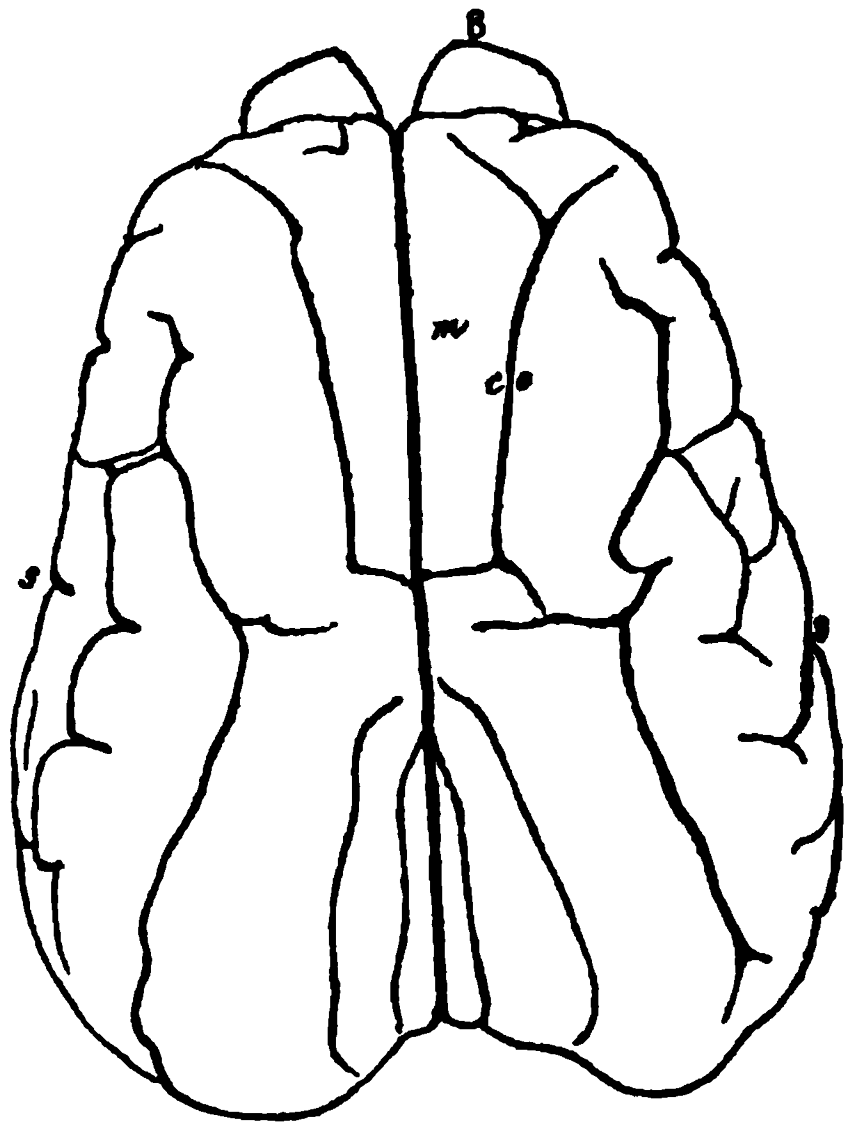


FIG. 28.—Vertex view of brain of *Dicotyles torquatus* (Peccari).

and not to be bounded by a sigmoid gyrus. When the sigmoid gyrus is absent, I do not think that this or any other transverse fissure should be regarded as homologous with the cruciate fissure in the Carnivora.

The mesial surface of the ungulate brain possesses a distinct splenial fissure, which is frequently prolonged backwards and downwards to the tentorial surface; in many species, as in *Phacochœrus* and the common Pig (fig. 30), it is not continued forwards into the genual fissure, but is separated from it by a bridging convolution. In the Horse and Rhinoceros,[1] the

[1] Owen described and figured the brain of the Indian Rhinoceros (*R. unicornis*) in *Trans. Zool. Soc.*, 1850, and Garrod figured the brain of the Sumatran Rhinoceros in *Trans. Zool. Soc.*, vol. x. pl. lxx., and in Collected Scientific Papers. The brain of the Hippopotamus has been described by Peters (*Monats. d. Berliner Akad.*, 1854); Gratiolet, Paris, 1867; Macalister, *Proc. Roy. Irish Acad.*, vol. i., 1873-74; Garrod, *Trans. Zool. Soc.*, vol. xi., and in Collected Scientific Papers.

callosal convolution is partially divided into two tiers by a longitudinal fissure. The splenial fissure not unfrequently turns

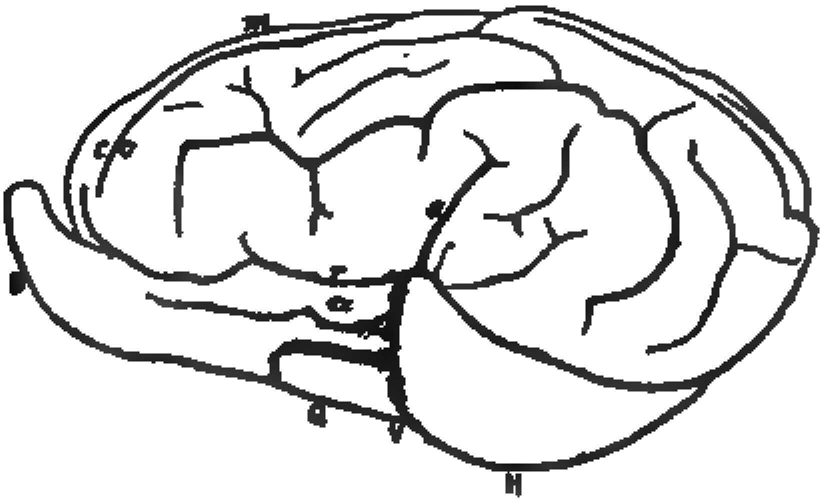


FIG. 29.—Cranial surface of hemisphere of *Sus scrofa* (Pig).

FIG. 30.—Mesial surface of hemisphere of *Sus scrofa*.

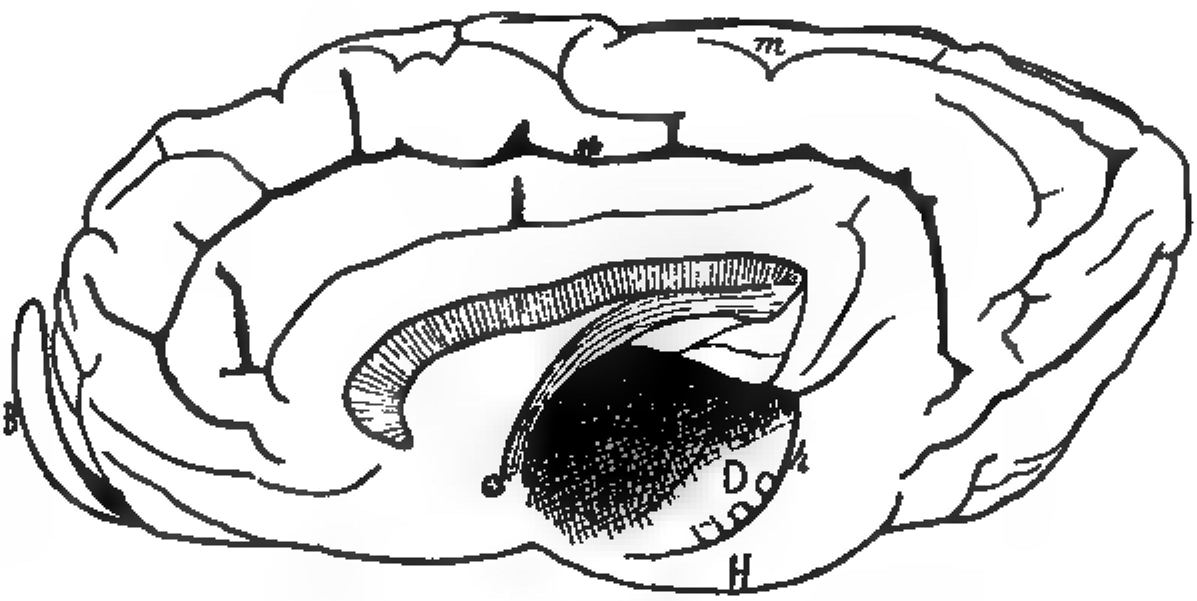


FIG. 31.—Mesial surface of hemisphere of *Equus caballus*.

upwards to the margin of the pallium (fig. 30) to become continuous on the cranial surface with either the coronal or the

lateral fissure, as in the Pig and Gazelle. I have seen in the brains of *Ovis* and *Bos* the splenial fissure reach the margin of the pallium without being continuous with either of these fissures; whilst in *Equus* it sends an offshoot as far as the edge of the mesial longitudinal fissure. In *Dicotyles* the splenial fissure does not reach the margin of the hemisphere, but is prolonged forwards into the genual fissure.

In the Cetacea the researches of Beauregard and Guldberg, as well as my own observations on *Phocæna, Globiocephalus, Monodon,* and *Balænoptera* have satisfied me that the convolutions on the cranial surface are arranged in great arcuate tiers surmounting the Sylvian fissure.

In the Narwhal (*Monodon*), and in *Balænoptera rostrata*, for

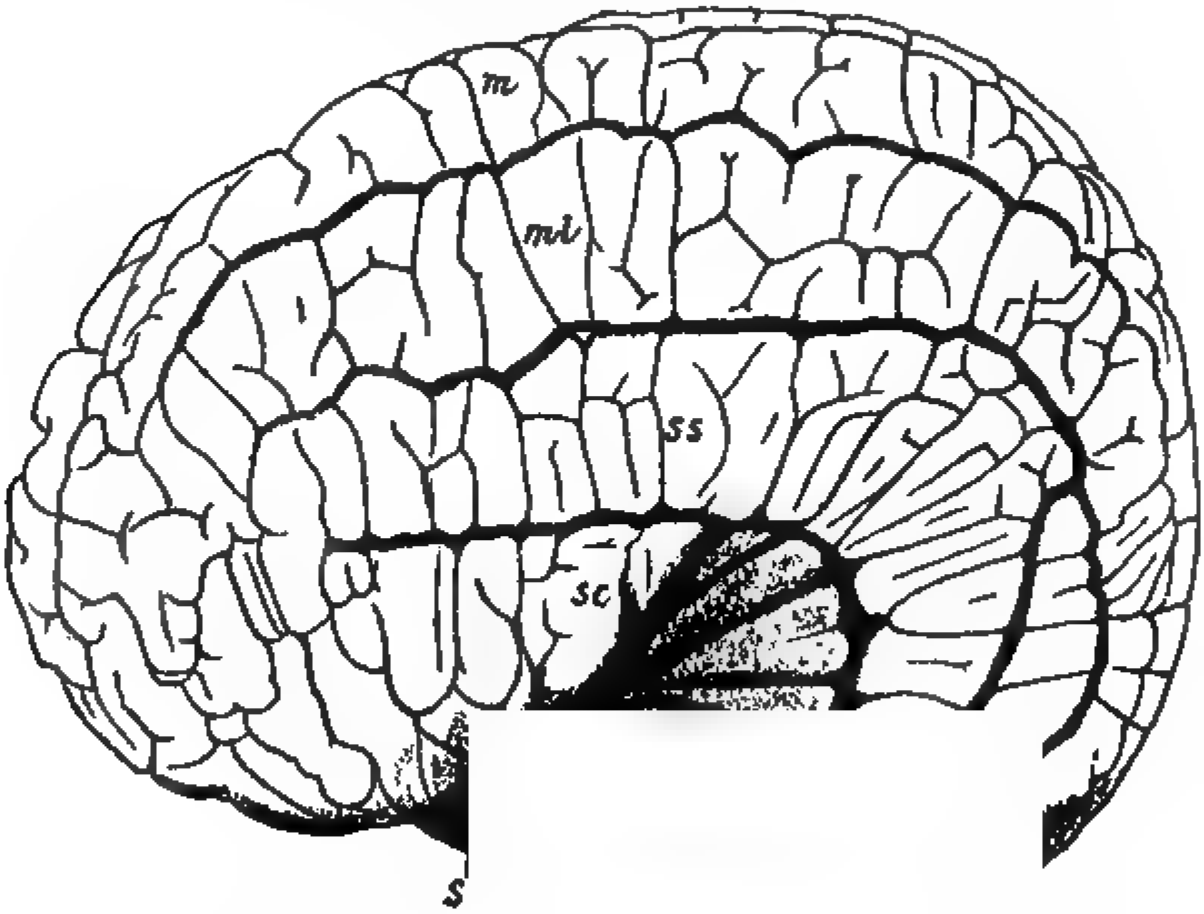


FIG. 32.—Cranial surface of the hemisphere of *Monodon monoceros* (Narwhal).

example, the tiers are four in number, and are separated from each other by arcuate fissures. The tiers may be named from above downwards, marginal, medio-lateral, supra-sylvian, and Sylvian. Each of these tiers is in its turn broken up into secondary convolutions, so that the whole cranial surface of the pallium is

highly convoluted. Fissures which may be termed præ-sylvian and coronal may also be recognised.

The mesial surface of the hemisphere may be described from *Balænoptera rostrata* (fig. 33). The corpus callosum is surmounted by a gyrus fornicatus, which may be traced from the perforated or quadrilateral space as a great arcuate convolution,

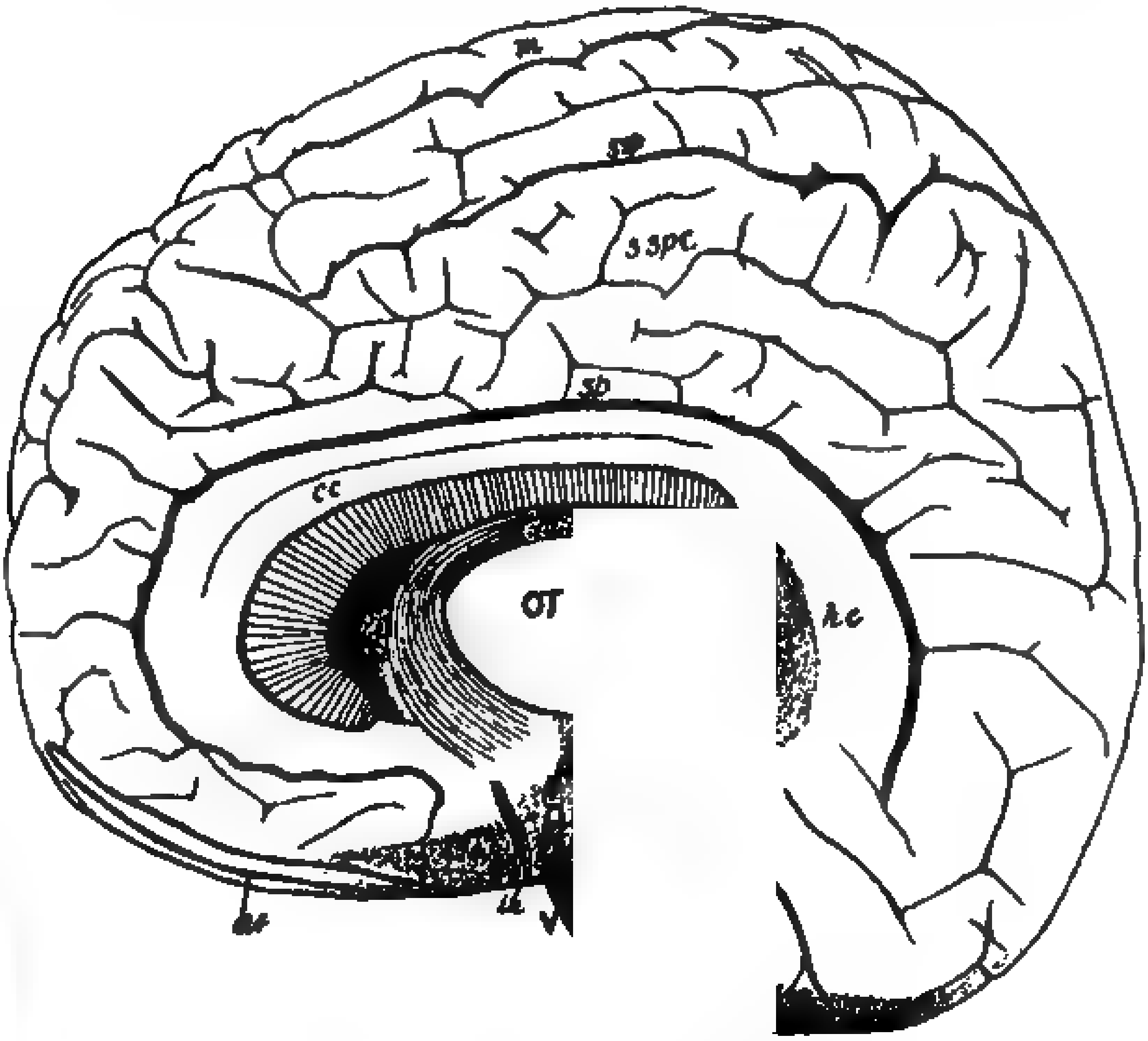


FIG. 33.—Mesial surface of the hemisphere of *Balænoptera rostrata.*

at first upwards and forwards as the callosal convolution (*cc*), and then backwards and downwards behind the splenium, where, as the gyrus hippocampi (*hc*), it becomes continuous with the lobus hippocampi. The callosal part of this convolution is partially subdivided into two tiers by a longitudinal fissure. The splenial fissure forms the upper boundary of the gyrus fornicatus in its whole length, and consists of the genual and splenial fissures continued into each other. It is crossed near the lobus hippocampi by two retro-limbic gyri.

The inner face of the hemisphere above the splenial fissure has a high vertical diameter, is greatly sub-convoluted, and is divided by a supra-splenial fissure (*ssp*) into a supra-splenial and a marginal convolution. The tendency to the formation of secondary or tertiary convolutions is more marked in the Cetacean than in any other brain, and it probably reaches its maximum in the brain of *Globiocephalus melas*.

In the genera of Primates which possess convolutions, and in Homo, the three groups of fissures and convolutions, longitudinal, vertical transverse, and arcuate, are present, and even in the smooth-brained Marmoset, a Sylvian fissure is seen (fig. 36). The longitudinal arrangement is well shown in the hemisphere of Man and the anthropoid Apes. It has its best representatives in the marginal, and in the upper, middle, and lower frontal

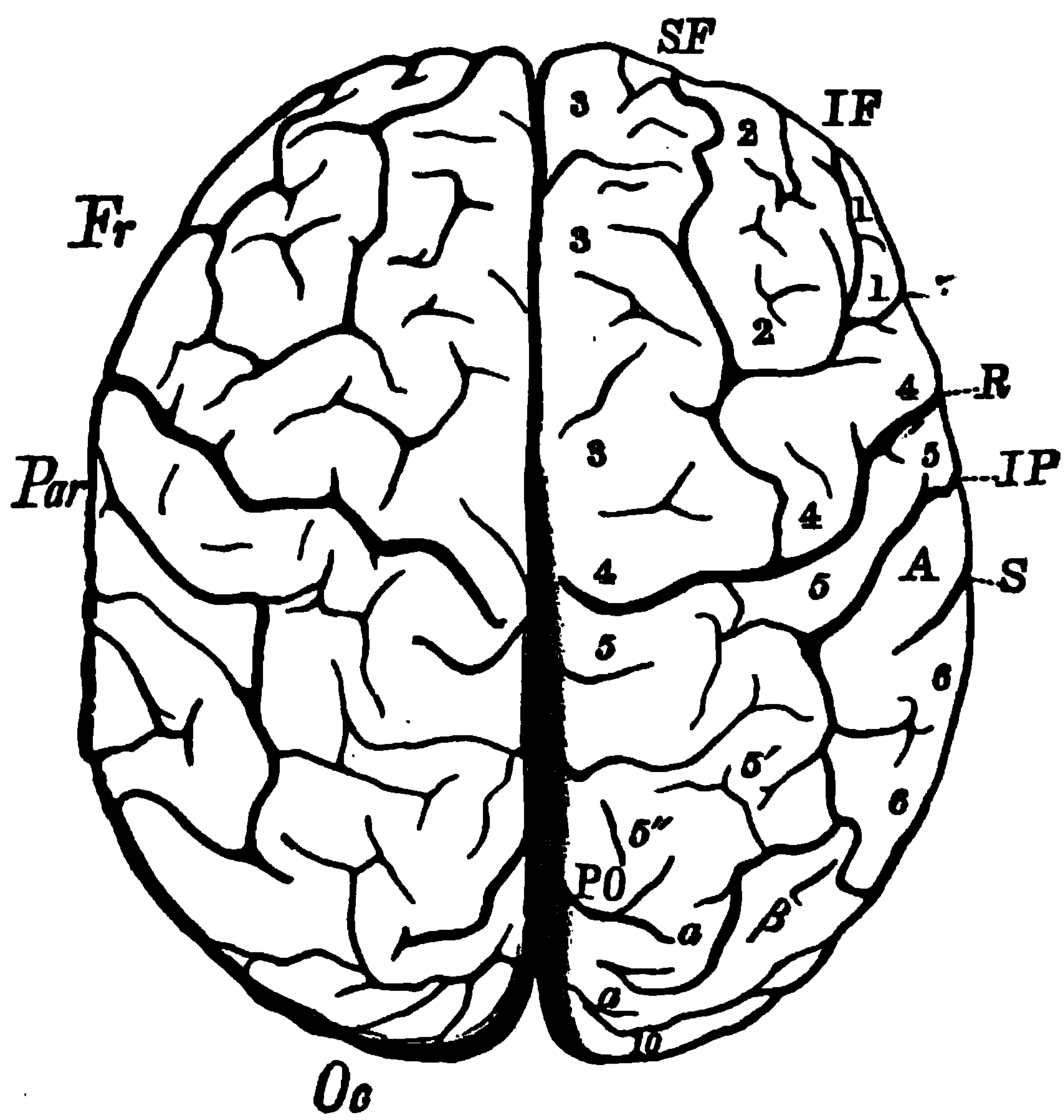


FIG. 34.—Vertex view of the human brain.

convolutions. The arcuate arrangement is seen in the more posterior convolutions of the parietal lobe, which are continuous through the bridging convolutions with the convolutions of the occipital and the temporo-sphenoidal lobes. The Sylvian fissure is surmounted by these convolutions. The

continuity of this arcuate arrangement with the convolutions of the frontal lobe is, however, disturbed by the magnitude and importance of the two great vertical transverse or central convolutions, named *ascending frontal* and *ascending parietal*, and of the *central fissure*, or *fissure of Rolando*, which lies between them (figs. 34, 35).

I1

FIG. 35.—Vertex view of the brain of a Chimpanzee.[1]

It is a question if the fissure of Rolando is present in any other brains than those of Apes and Man. It has been looked for more especially in the carnivorous brain, and several opinions have been expressed on the subject. A certain similarity in direction with the crucial fissure has led several authorities to regard the fissure of Rolando as homologous with it, and the anterior and posterior limbs of the sigmoid gyrus as the homologues of the ascending frontal and parietal convolutions. Broca and other French anatomists again look upon the præ-sylvian fissure as representing the fissure of Rolando. Owen, Pansch, and Meynert have regarded the coronal fissure as the homologue

[1] This figure and fig. 41 are reproduced from my memoir "On the Bridging Convolutions in the Brain of the Chimpanzee," *Proc. Roy. Soc. Edin.*, Feb. 19, 1866, p. 578.

of the fissure of Rolando, and several reasons, more especially of a physiological nature, may be urged in support of this position. I shall not, however, pursue the subject further on this occasion, as I have elsewhere discussed it at considerable length.[1]

But in the brains of the convoluted Apes and of Homo, another vertical transverse fissure of great importance has to be studied, viz., the *parieto-occipital fissure*, which the descriptive anatomist is in the habit of regarding as mapping out on the surface of the hemisphere the interval between the parietal and the occipital lobes. In the Ape's brain it is distinctly marked both on the cranial and mesial surfaces; in the human brain, though very distinct on the mesial surface, it is obscured on the cranial surface by bridging convolutions (figs. 34, 35, 40, 41).

But the question arises for consideration, Can there not be an occipital lobe without a parieto-occipital fissure? This question must, I believe, be answered in the affirmative. The test of an occipital lobe is not the presence of a parieto-occipital fissure, for the lobe exists before this limiting fissure is produced, and the true sign of the presence of this lobe is the backward growth of the hemisphere, so that it lies above the cerebellum, and with this growth a corresponding extension of the ventricular cavity backwards takes place in the form of a posterior cornu. Associated with the posterior cornu is the formation of a calcarine fissure on the mesial surface of the hemisphere, through which is produced a calcarine elevation in that horn known as the hippocampus minor.

That this is the real explanation of the signification of the

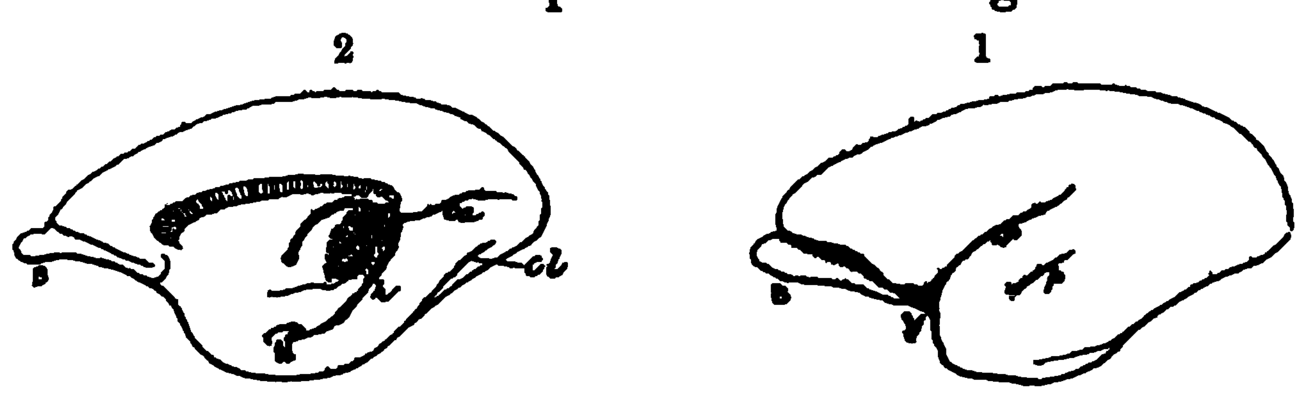


FIG. 36.—Hemisphere of *Hapale jacchus* (Marmoset). 1, cranial surface; 2, mesial surface.

occipital lobe is proved by what is seen in the Marmoset Monkey (*Hapale jacchus*). In this animal the cerebrum is extended

[1] See my "Memoir on the Seals" in the *Challenger Reports*, part lxviii., 1888, and in the *Journal of Anatomy and Physiology*, vol. xxxii. p. 554.

as far back as to cause the cerebellum to be below the hinder part of the cerebrum. On the cranial surface the Sylvian fissure is very distinct, and a shallow depression in the temporo-sphenoidal lobe marks the position of a rudimentary parallel fissure. Otherwise this surface is quite smooth. On the mesial surface there is no splenial fissure, but opposite the splenium a distinct calcarine fissure is continuous with the hippocampal fissure, and extends back almost as far as the tip of the posterior end of the cerebrum. Within the hemisphere a posterior cornu and calcar avis are present. There is no trace of a parieto-occipital fissure.

Confirmation of this view can be obtained from the brain of the Prosimian Javan loris (*Stenops*), in which a calcarine fissure on the mesial and tentorial surface proves the presence

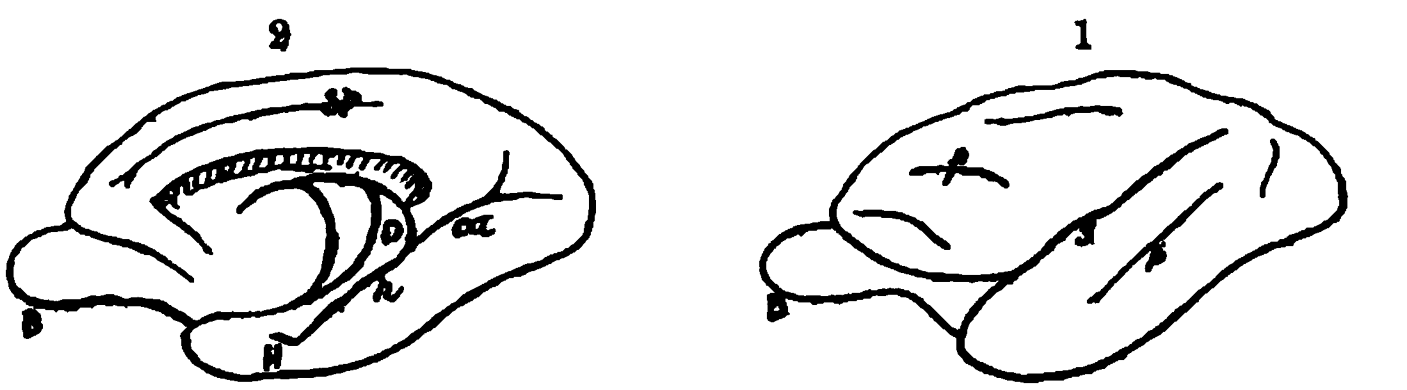


FIG. 37.—Brain of Stenops (after Flower). 1, cranial surface; 2, mesial surface.

of both posterior cornu and calcar avis, *i.e.*, of an occipital lobe. In this animal there is no parieto-occipital fissure. Moreover, *Lemur nigrifrons* exhibits a similar arrangement.

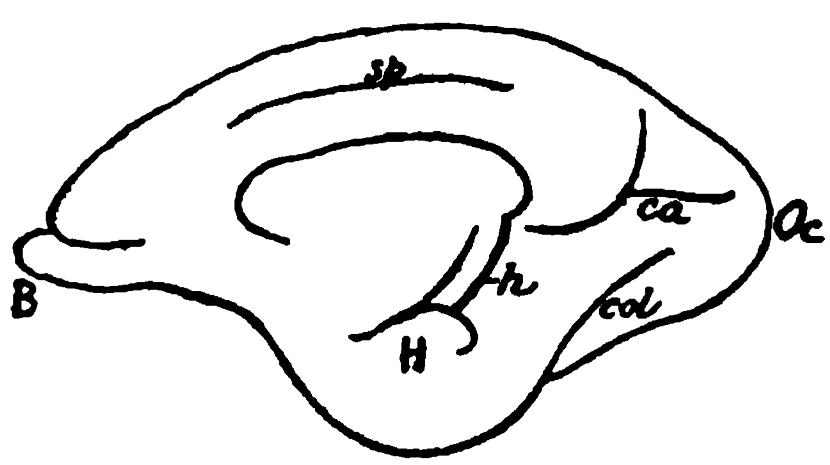


FIG. 38.—Hemisphere of *Lemur nigrifrons*, mesial surface (after Flower).

Hence, if the surface of the hemisphere be examined with the view of determining the presence of an occipital lobe by the existence of a fissure, the calcarine fissure is that which is to be regarded as of primary importance, and the parieto-occipital fissure appears at a later period in the evolution of the mammalian brain. What then is the signification of the parieto-

occipital fissure? It is, I believe, nothing more than a folding on the cranial and mesial surfaces of the hemisphere, expressive of and due to the great development of the grey matter of the cortex and its associated white matter in the region where the posterior cornu branches backwards from the body of the ventricle. This fissure is absent in the Prosimii and in the Platyrrhine Marmoset, but it is present in Man, the Apes of the Old World, and in the larger American Monkeys as *Pithecia*, *Ateles*, and *Cebus*.

From this view of the case I cannot, as is done by some anatomists, regard the occipital lobe as a bud, more or less independent, springing out of the hinder part of a parietal lobe and separated from it by a constricting fissure. In my judgment the occipital lobe is due to a continuous growth of the hemisphere and of the ventricular space contained within it, correlated with an antero-posterior elongation of the cranial cavity, and a depression downwards and forwards of the cerebellum and medulla oblongata; so that the foramen magnum is not at the posterior end of the cranium, but is thrown some distance forwards on to its basal surface.

The period of appearance in the course of the evolution of the mammalian brain of a fissure of Rolando having a position and direction such as we are familiar with in the brains of Primates, may also engage our attention for a few moments.

In the Prosimian *Stenops* and *Lemur nigrifrons* it is absent.

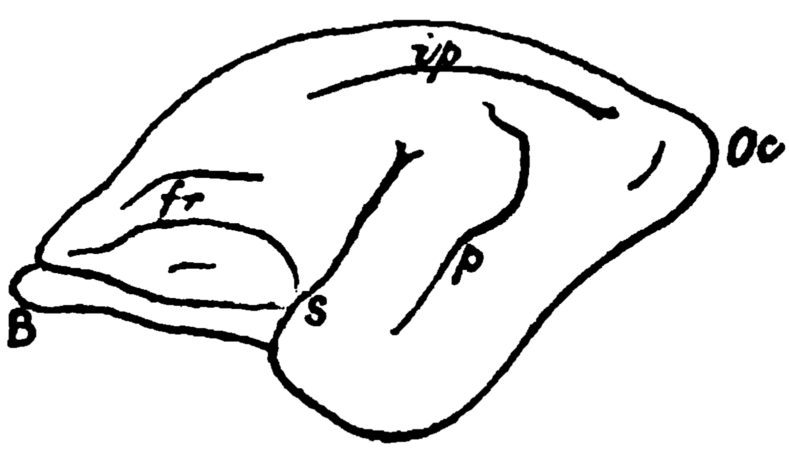


FIG. 39.—Hemisphere of *Lemur nigrifrons*, cranial surface (after Flower).

No vestige of it can be seen in the Platyrrhine Marmoset; but it is distinct in the Platyrrhine genera, *Pithecia*, *Ateles*, *Cebus*, &c. But, notwithstanding its absence in the *Lemuridæ* and the smaller Apes of the New World, there can be no question, from the general conformation of the hemispheres in these

animals, that they contain potentially both frontal and parietal lobes. It is true that the Marmoset has a perfectly smooth hemisphere in front of and above the Sylvian fissure; but the hemisphere in *Stenops* possesses in its more anterior part rudimentary fissures extending antero-posteriorly, which mark the commencement of a differentiation into tiers of convolutions extending in a sagittal direction, such as one is familiar with in the frontal lobe of the higher Apes. Corresponding antero-posterior fissures exist also in *Lemur nigrifrons* (fig. 39), and another fissure is placed further backwards (*ip*), which is probably the homologue of the intraparietal fissure in the higher brains. Hence we cannot but conclude that a cerebral hemisphere may possess both a frontal and a parietal lobe, even when no trace of a fissure of Rolando exists, just as it may have an occipital lobe without a parieto-occipital fissure.

A distinct temporal lobe also exists in the Prosimian brain, and both in *Lemur nigrifrons* and *Stenops* a fissure parallel

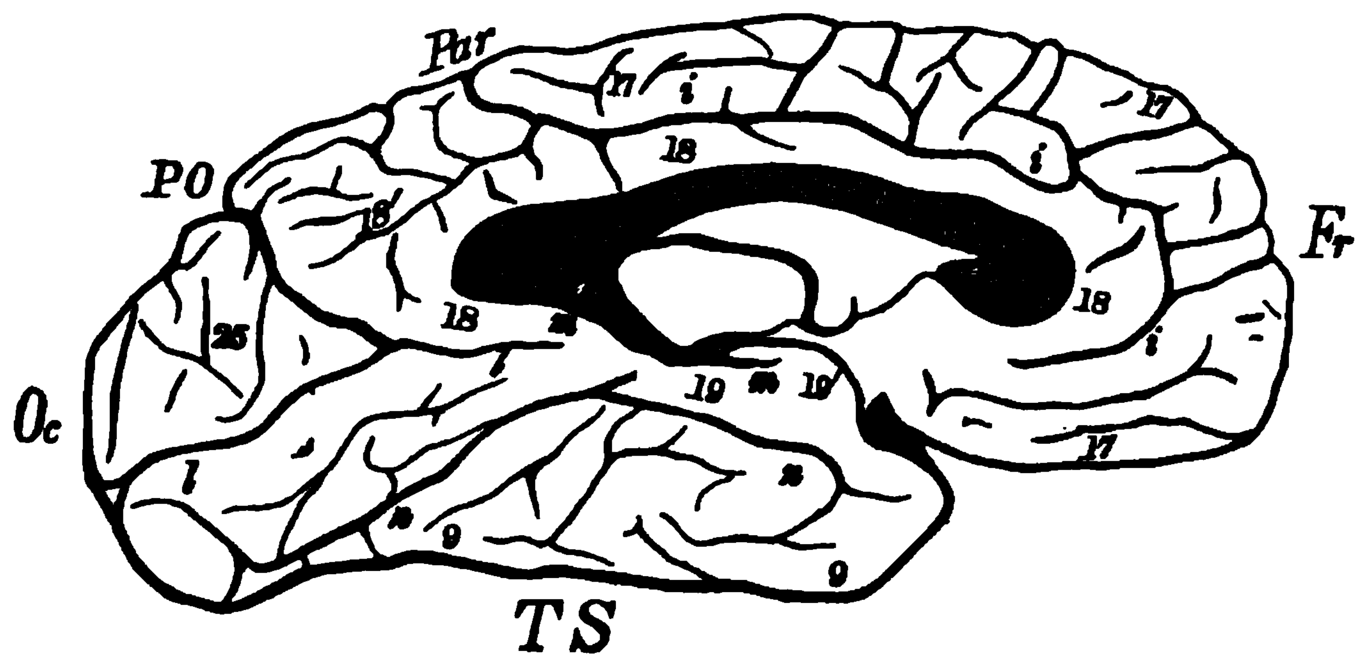


FIG. 40.—Mesial surface of the left hemisphere of Man.

to and behind the Sylvian fissure may be seen in this lobe. Even in the smooth-brained Marmoset a temporal lobe elongated downwards and forwards is present, and a rudimentary parallel fissure can be recognised; whilst in the larger American Monkeys, like *Cebus* and *Ateles*, and still more in the Old World Apes and in Man, the general characters of this lobe are known to all anatomists.

Both *Lemur nigrifrons* and *Stenops* possess a calloso-marginal or splenial fissure, so that the marginal convolution is differentiated from the callosal (figs. 37, 38), whilst in the

Platyrrhine Marmoset this fissure is absent, and the callosal and marginal areas of the mesial aspect of the hemisphere present a continuous plane surface (fig. 36). In this respect, the *Lemuridæ* are in advance of the genus *Hapale* and more closely approximate to the arrangement found in the higher Apes and in Man.

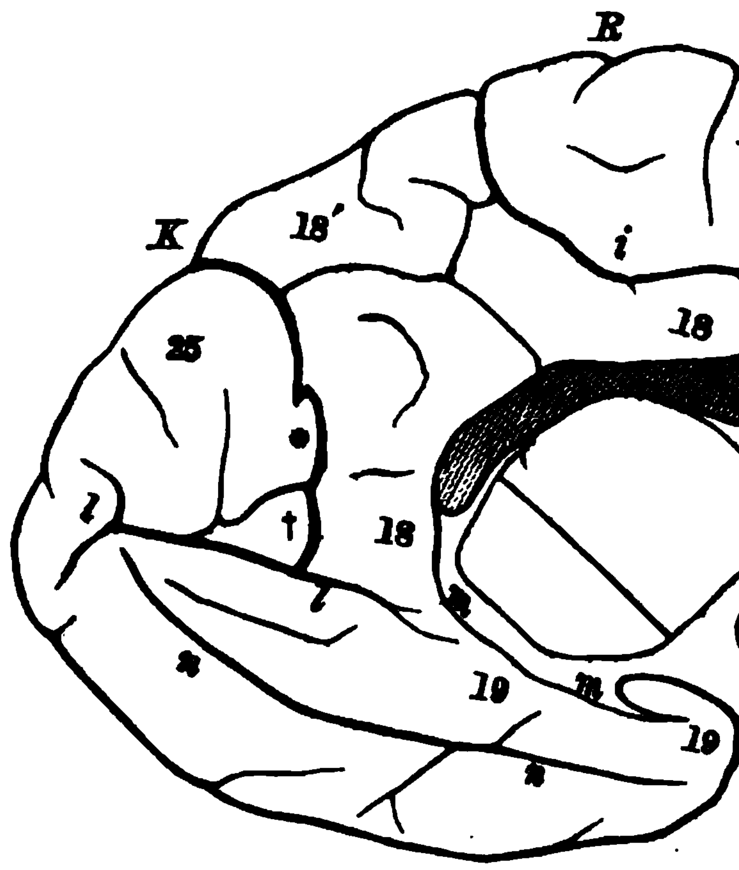


FIG. 41.—Mesial surface of the left hemisphere of a Chimpanzee.

In the human brain and in the Ape the calloso-marginal (splenial) fissure is very distinct, and separates the callosal and marginal convolutions from each other. It is usually prolonged upwards to reach the upper margin of the hemisphere, and it may be continued back into the parieto-occipital fissure. It separates from each other the callosal and marginal convolutions. On the tentorial surface of the hemisphere, and below the calcarine fissure, is the *collateral fissure* (*n*), which forms the posterior boundary of the hippocampal convolution[1] (figs. 40, 41).

In the human brain and that of the Ape, more especially the anthropoids, the orbital surface of the frontal lobe is divided by fissures into convolutions. A distinct olfactory fissure which demarcates a gyrus rectus (fig. 42, 17) is present. External to

[1] The calloso-marginal fissure in the human brain is apparently the conjoined genual and splenial fissures which in many lower mammals are not continuous with each other. When prolonged into the collateral fissure, as is frequently the case in Man and the higher Apes, it then forms a great arcuate fissure forming the upper boundary of the gyrus fornicatus, for which Waldeyer has suggested the name *sulcus fornicatus*.

the olfactory peduncle is a branching fissure which many years ago I named the *triradiate fissure.* The term intra-orbital fissure is, however, more appropriate, and the convolutions

FIG. 42.—Orbital surface of the microsmatic brain of Man.

bounding it externally and internally, may be named, as in the Walrus and Seal, internal and external supra-orbital.

The consideration of the production of the fissures of the cerebral hemispheres, and the consequent conversion of a smooth brain into one with convolutions, is a matter of so much interest that I cannot conclude without making some reference to it. I believe that the mode of production of a convoluted surface is to be regarded as in the main a physical problem and to be studied from that point of view. Three great factors require to be taken into consideration in the discussion of this problem. *First*, the growth of the grey matter of the cortex and its associated white matter. *Second*, the growth of the great ganglia at the base of the hemisphere and the connections which these ganglia have through the intermediate strands of nerve-fibres with the cortical grey matter. *Third*, the pressure

on the hemisphere due to the resistance offered by the parts which enclose it.

As regards the growth in superficial area of the grey matter of the cortex, it is universally recognised that a convoluted surface gives a much more extensive superficial area to the cortex of a brain than it is possible to obtain in a brain of a corresponding volume when the cortex is smooth. The presence of convolutions expresses, therefore, a more extended area of grey matter, and a corresponding modification in the strands of nerve-fibres connected with it.[1] It is very probable that this growth of the cortex may be affected by the tension exercised on it by the nerve-fibres passing into its deep surface from the subjacent parts of the encephalon. It has been suggested, for example, that the depression of the island of Reil at the bottom of the Sylvian fissure is due to its relation and connection with the subjacent corpus striatum checking its extension towards the surface. The cortical matter forming the lips of the Sylvian fissure, having no such check, would therefore project beyond it, and conceal it in such brains as those of Man, Apes, and the Cetacea.

But another chief factor in the production of the convolutions may be looked for in a resistance offered to the growth of the cortex along certain lines or planes. The parts which, from their situation, might be regarded as capable of offering such resistance are the blood-vessels of the pia mater; also the dura mater and the bones which form the walls of the brain cavity.

[1] The influence which the convolutions have on the relation between the superficial area and the volume of the brain is expressed by M. Baillarger as follows:—"La différence entre le rapport des volumes et des surfaces est le résultat de cette loi mathématique; que les volumes des corps semblables sont entre eux comme les cubes de leurs diamètres, tandis que leurs surfaces sont entre elles comme le carré de ces diamètres, ce qui donne des proportions très différentes. Le cerveau subit cette loi à laquelle il est cependant soustrait en partie par l'existence des circonvolutions."—Quoted by M. Broca in his essay "Le Grand Lobe Limbique, &c.," *Revue d'Anthropologie*, 1878.

When this address was delivered in Berlin I had not seen the report in the *Brit. Med. Jour.* of Aug. 2, of the address delivered by Prof. Cunningham of Dublin at Birmingham in the previous week, in which the influences which produce the cerebral convolutions are discussed at considerable length, and the various theories which have been advanced are stated with force and lucidity.

As regards the possibility of pressure being effected by blood-vessels, the following reasons may be given :—

It is well known that, in several parts of the body, grooves may be produced by the pressure-pulsation of blood-vessels even on the bones themselves. Thus the arteria facialis can groove the inferior maxilla, and the arteria subclavia the 1st rib. Veins also may by pressure occasion grooves such as are produced by the lateral and superior longitudinal venous sinuses in the inner table of several of the cranial bones. Much more, therefore, is it possible to conceive that the pressure of the vessels of the pia mater may produce furrows on the surface of the soft cerebral cortex. There is indeed no difficulty in satisfying oneself that furrows can be produced by this agency. Any one who carefully strips off the pia mater from the cerebrum of a smooth-brained animal may see branching furrows on the cortex corresponding to the arterial distribution in the pia mater. In the developing brain, also, the pressure of the choroid plexuses on those parts of the wall of the hemisphere-vesicle which consist almost, if not quite exclusively, of epithelium, causes an involution of the thin wall of the hemisphere towards the ventricle, and a consequent furrow or fissure on the surface. Even in the convoluted brains one may, in certain localities, obtain evidence of furrowing of the surface of the cortex by arterial pressure.

But, notwithstanding all these examples, I do not attach much importance to the influence of arterial pressure as a factor in the formation of those fissures which I have been describing on the surface of the cerebral hemispheres. If they were of fundamental importance in this connection, then the pattern of the cerebral fissures and convolutions should precisely correspond with the distribution of the blood-vessels, which is by no means the case. Even when a blood-vessel follows the line of a fissure, the association between them is in all probability because the fissure offers a convenient and easy passage for the vessel, and not because the vessel by its pressure produces the fissure. As is well known, the middle cerebral artery is lodged in the Sylvian fossa and fissure, the depth of which is, without doubt, determined by other conditions than the pressure of this artery and its branches. From the examination of the injected braiu

of a *Marmoset*, I have seen a main artery occupying for some distance the Sylvian fissure, and then leave the fissure to pursue a course entirely independent of it. The relation between them is clearly, therefore, of secondary importance. Similarly the larger arteries of the cerebellum have not a definite relation to the numerous folia and fissures into which its surface is divided.

The resistance offered by the walls of the cranial cavity, comparatively unyielding as they undoubtedly are in the earlier stages of development, and still more unyielding as the ossification of the cranial bones advances, offers, I believe, another explanation of the production of a convoluted surface. The cranial cavity, when viewed in its relation to brain-growth, is not one chamber but three chambers. The single large cavity observed in the macerated skull is divided, when the dura mater is in position, into three chambers,—a pair of superior chambers separated from each other by the falx cerebri, in which the two cerebral hemispheres are lodged, and a single inferior chamber separated from the two superior by the tentorium cerebelli, and destined for the lodgment of the cerebellum. The resistance offered by the walls of the chambers in which the hemispheres are contained is due partly to the vaulted roof of the skull, partly to the tense and resisting falx cerebri, and partly to the equally tense tentorium cerebelli. The vaulted cranial roof has a continuous arched surface, but, where it is joined by the attachment of the falx and tentorium, a very definite angle is formed, so that the chamber for each hemisphere is, when seen in vertical transverse section, triangular in its shape. At each angle of this triangular chamber the soft and easily-moulded grey cortex is subject to pressure on two aspects, so that if the growth of the grey matter and hemispheres generally is at a greater rate than the growth of the chambers in which they are contained, their surfaces would become folded, and the direction of these foldings would have a relation to the lines or planes of resistance.

The primary fissure of the entire cerebrum is the mesial longitudinal fissure, the formation of which, at a very early period of development, separates the originally single hemisphere-vesicle into two hemispheres. The researches of Mihalkovics have shown that the production of this fissure is

associated with the development of the falx cerebri, which, by its growth, pressure, and resistance, produces a depression in the mesial plane of the hemisphere vesicle, which, as it increases in depth, leads to the formation of the longitudinal mesial fissure.

We have here, therefore, distinct evidence that pressure and resistance on the vertex of the embryonic cerebrum have produced a fissure which, in this case, extends in the longitudinal or sagittal direction.

But the examination of the fissures and convolutions already made has taught us that in each hemisphere fissures and convolutions, extending in a sagittal direction, *i.e.*, parallel to the great longitudinal fissure, are a very usual arrangement, and their production is, I believe, in part due to the growth of the hemisphere chamber in vertical diameter not keeping pace with the growth in the vertical direction of the cerebral cortex; so that the cortex folds on itself in the longitudinal or sagittal direction, *i.e.*, at right angles to the direction of the pressure.

The production of vertical transverse fissures and of convolutions having a corresponding direction may, in like manner, be due to the resistance offered to the antero-posterior growth of the hemisphere, owing to the length of the cranial cavity not being proportioned to the growth of the hemisphere in the same direction. A striking illustration of this is furnished by the brain of the Cetacea. As is well known, the cranial cavity in these animals is antero-posteriorly compressed, so that the sagittal diameter of the brain is much less than the transverse. Now, if we examine the hemisphere of such a cetacean as the Narwhal (fig. 32), we see that, in addition to the arcuate fissures and convolutions referred to in the descriptive part of this address, the surface of the hemisphere is crowded with fissures and convolutions, the general direction of which is vertically transverse, *i.e.*, at right angles to the direction of the pressure.

As regards the arcuate fissures and convolutions, it is possible that they may be modifications of a system of fissures and convolutions, originally arranged longitudinally, which become altered in direction by the development of a temporal lobe growing downwards and forwards, and by a change in the direction of the tentorium cerebelli from a vertical plane to one

which is more nearly horizontal, so that the cerebellum is no longer posterior, but inferior in position.

The hemisphere, even in the most highly convoluted mammalian brains, is originally smooth on its surface in the embryo, and the convolutions appear and gradually assume their characteristic arrangement as the ossification of the walls of the cranial box advances. The resistance offered by the surrounding parts at last becomes so great that the growth of the cortex cerebri, and of the hemisphere generally, ceases, and the convoluted surface then exhibits the arrangement, which is characteristic of the species and of the individual.

No more striking example of a highly convoluted brain can be referred to than that of Gauss, the great mathematician, as figured by Rudolf Wagner.[1] By way of contrast, the brain of the Bushwoman figured by Mr John Marshall[2] may be looked at. In both, the plan of arrangement of the fissures and convolutions characteristic of the human brain is present; but the tortuosity and subdivision of the convolutions in the brain of Gauss contrast strongly with their comparatively simple disposition in the Bush brain. In volume Gauss's brain surpassed that of the Bushwoman, and his cranial cavity was, of course, larger; but it is not unlikely that in him the rate of brain-growth so far exceeded the rate of expansion of the cranial cavity that the resistance offered by the walls of the latter induced the complex secondary foldings on the surface of the pallium, which give to his brain its individual character.

Once a specific arrangement has become established, it is then transmitted from generation to generation by hereditary influence, so that an anatomist who has made the convolutions of the mammalian brain a subject of study can, by an inspection of the cortex cerebri, determine with tolerable precision the species to which the brain belongs. Further, the constancy of the morphological specialisation in each species points to functional differences in the areas thus differentiated from each other.

From the study of the surface of the hemisphere in the whole series of Mammalia, it is obvious that the convolutions do not exhibit a progressive and continuous development from the lower

[1] *Morphologie des Menschlichen Gehirns*, 1860.

[2] *Phil. Trans.*, 1863.

mammals up to the higher Apes and Man. On the contrary, the brain follows apparently in each order its own plan of evolution, so that it is not uncommon to find in the same order some species with smooth brains, others possessing brains with feeble convolutions, others again with convolutions much more complicated in their arrangement. Examples of these modifications within an order have already been referred to in the Monotremata, the Marsupialia, and the Primates. The study, therefore, of the convoluted surface of the pallium in the Mammalia does not sanction the view that there has been a continuity of evolution from Ornithorhynchus to Homo in a direct longitudinal series, for well-convoluted brains may exist in an order, the general construction of the animals forming which may be inferior in other respects; whilst some species, in another order presumably higher in its organisation, may have the brain only feebly convoluted, or perhaps even with a smooth surface. This proposition may be made more clear if I give an example.

The brains of the larger Carnivora, and still more those of the Pinnipedia, have, as is well known, an elaborate arrangement of convolutions,

In the Lemuridæ, again, the convolutions are feeble, and in the Platyrrhine Marmoset the surface of the brain is practically smooth. Hence it is difficult to conceive that the brain of the Lemurs, or of the Primates, has been evolved out of the Carnivorous brain, at least after the cortex of the cerebrum in this latter order had begun to assume a convoluted arrangement. If the Primates had been evolved from the Carnivora, or even if the Lemuridæ had been derived from them, the branching off from a carnivorous stem must have occurred before the carnivorous brain became convoluted; for it is unlikely that in the process of evolution the convoluted brain could have disappeared and a smooth brain, such as we see in a Marmoset Monkey, have been its successor. The replacement of a convoluted brain by one with a smooth surface would be a retrograde or degenerative step, and not an evolution to a higher stage of development. A similar remark would also apply to the evolution of the Primates from ungulate, cetacean, or proboscidean mammals, in which the pallium had assumed a convoluted character.

CASE OF ABNORMAL ARRANGEMENT OF THE VEINS ABOUT THE POPLITEAL SPACE. By David G. Davidson, M.B., Leeds.

In the subject in which the abnormal arrangement occurs the popliteal vein occupies its normal position and relations in the space itself, but at the opening in the adductor magnus it gives off a very small branch which accompanies the femoral artery, while the main trunk of the vein passes up the back of the thigh, lying between the origins of adductor magnus and short head of biceps. It reaches the front of the thigh by piercing the adductors magnus and brevis immediately above the insertion of adductor longus, accompanying the femoral artery for the rest of the course, being joined at the upper part of Scarpa's triangle by the small branch which was given off at the opening in the adductor magnus.

The short saphenous vein lies to the outer side of the middle line in the lower part of the popliteal space, and soon piercing the fascia sinks deeply, to lie on the posterior ligament of Winslow. It has no connection whatever with the popliteal vein at this point, but continues its course vertically upwards, until it reaches a point three inches above the condyles of the femur, when it pierces the origin of the short head of biceps. Running for a short distance in the substance of the muscle, it next emerges, and joins the main trunk which we have seen passing up the back of the thigh. The long saphenous vein is double, but occupies the usual position.

NOTE ON A TUMOUR IN *ANODONTA CYGNÆA*, Linn. By Walter E. Collinge, *Honorary Assistant Curator to the Conchological Society of Great Britain and Ireland.*

In the January number of this *Journal*, 1890, Mr J. W. Williams describes a tumour found in a specimen of the well-known freshwater mussel *Anodonta cygnæa*. Up to the time of reading this paper, I had never met with any such in any of the freshwater conchifera, and it would appear from Mr Williams' remarks and my own observations that such occurrences are by no means common. Mr Williams found only one out of some seven hundred specimens he examined, and I have examined between two and three hundred, and have had the good fortune to meet with two. The specimens were collected in the lake in Roundhay Park, near Leeds, and are known to Conchologists as variety *Zellensis*.

The first specimen I met with had evidently been injured, for beneath the left lobe of the mantle, and close to the dorsal siphon, I found a hard muscular pyriform body about the size of a pea or slightly smaller; just above this, at the base of the left mantle lobe, was a somewhat elongated mass connected with both the mantle lobe and the outer gills. This structure had seriously interfered with the functions of the animal, for the whole of the posterior portion of both right and left valves of the shell were almost void of any nacreous substance and the calcareous portion in a loose laminated condition.

In the second case, the tumour was more in accordance with that described by Mr Williams, with this exception, that it was not connected with the mantle lobe by a pedicle.

Fig 1.

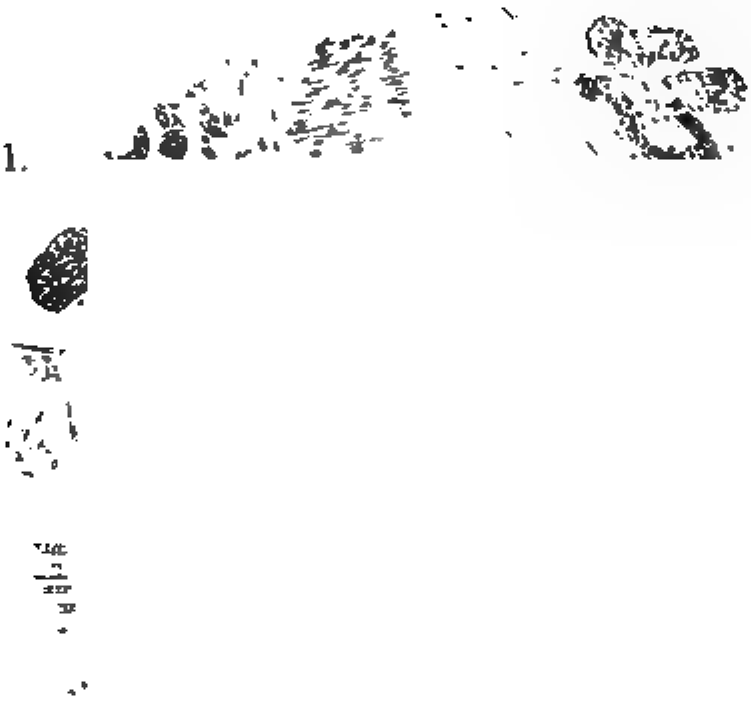


Fig. 2. (after His)

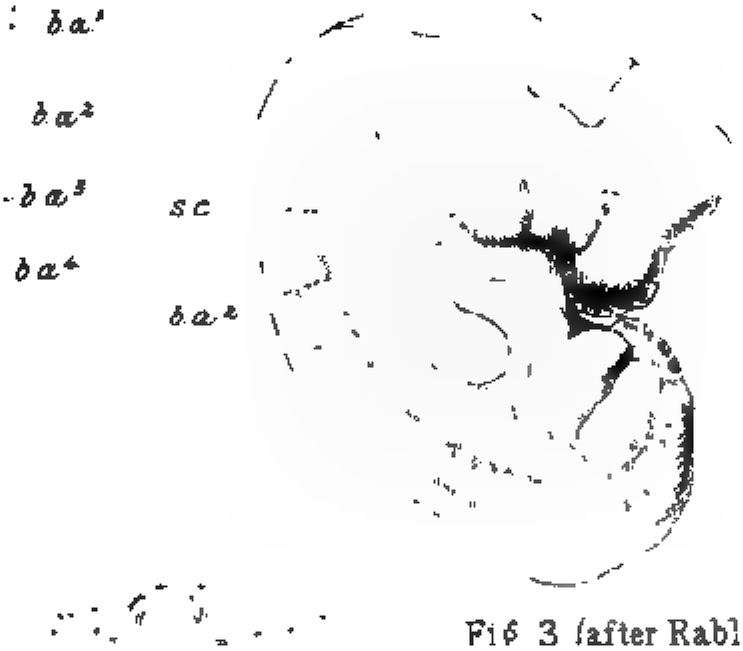


Fig 3 (after Rabl)

Fig 1a

Journal of Anatomy and Physiology.

THE THYREO-GLOSSAL DUCT.

By A. A. KANTHACK, B.A., B.Sc., F.R.C.S., *St Bartholomew's Hospital, London.* (PLATE III.)

Introductory Remarks.

IN all vertebrates, excepting the Cyclostomata, the glandula thyreoidea is developed from three parts, a mesial one and two lateral ones. These are primarily tubular outgrowths from the epithelium of the anterior or ventral bucco-pharyngeal wall. The mesial part is developed in the vicinity of the *second branchial arch*, while the lateral ones are developed *behind the last branchial arch in connection with the last branchial cleft.* These elements eventually fuse and form a horse-shoe-shaped mass which partially embraces the larynx. But at the time of fusion the lateral portions are so exceedingly small, that Kastschenko (1) apparently justly considers them of little importance in the development of the glandula thyreoidea. His (2), on the other hand, claims that the lateral portions form the voluminous lobes of the gland, while the mesial outgrowth corresponds to the isthmus. The same author also traces some connection between the mesial portion and the development of the base of the tongue. According to His (2), the tongue is developed in two parts—(*a*) an anterior, and (*b*) a posterior one. The anterior one, which corresponds to the body and point of the tongue, is developed from the *tuberculum impar* on the floor of the mouth, while the base of the tongue owes its origin to two masses in the neighbourhood of the second and third branchial arches. The two parts eventually meet along a V-shaped fold, and at the vertex of the V a deep depression, the *foramen cæcum,* is found. Now, between these three masses which form the tongue, there is a deep sinus,

which, according to His (2), corresponds to the outgrowth of the pharyngeal epithelium in other vertebrates, which is the progenitor of the thyreoid gland. As these masses approach one another, the sinus is transformed into an epithelial vesicle, which for some time communicates with the surface of the tongue by means of a narrow duct, the *ductus thyreoglossus*. As the thyreoid gland gradually moves downwards, this duct is lengthened out and converted into a narrow epithelial tube, the osteum of which is always found at the foramen cæcum. As a rule, the foramen is all that is left of the duct, but at times the latter persists more or less. Thus at times a canal may be traced from the foramen cæcum to the body of the os hyoideum, the *ductus lingualis*. In other cases the middle lobe of the thyreoid gland may be traced, as a narrow tube, as far as the hyoid bone, the *ductus thyreoideus*. Again, the glandulæ supra- and præhyoideæ are probably derived from this ductus thyreoglossus. So far His.

Mr Bland Sutton (3), in his lectures on "Dermoids," fully endorses His's views, and draws certain conclusions from them with regard to the formation of some tumours in the mid-line of the tongue. "According to his dissections, the lingual duct seems to be present once in every ten subjects examined." Mr Sutton refers to several cases of new growths in the base of the tongue, and practically describes them as "lingual goîtres." Soon afterwards Wolf (4) gave a detailed account of a similar tumour. These anatomical and pathological phenomena seemed deserving of special notice, and it was therefore resolved to examine fœtuses, children, and adults, with a view of ascertaining the frequency and history of the "lingual duct."

Method employed.

1. *Adults.*—The tongues of more than 100 individuals were used. A fine silver probe was first pushed into the foramen cæcum as far as it would go. The thyreoid gland was next dissected out, and when a *lobus pyramidalis* existed, its connections with the hyoid bone carefully examined. The muscles of the tongue were separated with care close to their attachment to the hyoid bone until the *septum linguæ* became evident. Finally, the whole basis linguæ was cut with a sharp

razor into numerous thin (coronal) slices, and each examined under a magnifying glass. Whenever a section presented anything abnormal, or in any way resembling a duct, it was kept for microscopical examination. A lobus pyramidalis was always examined histologically.

2. *Fœtuses and Infants.*—Of these sixty were used, the fœtuses varying from two and a half to eight months. In each instance the basis linguæ and adjoining parts were hardened in alcohol, embedded in celloidin (or frozen), and cut in series. In most cases the thyreoid gland was carefully dissected, and whenever a lobus pyramidalis was found, it was examined microscopically. The sections, whether of the tongue or the lobus, were in all cases at right angles to the long axis.

Results of the Examination of Adult Tongues.

1. *The lobus pyramidalis.*—Following a suggestion by His, the first point to be decided was whether the "cornu medium of the glandula thyreoidea" is always accompanied by a ductus lingualis, or whether the one may exist without the other. After an extensive examination, it may be said with certainty that the presence of a cornu medium does not even necessitate the existence of a foramen cæcum, much less of a ductus lingualis.

It is hardly necessary to waste any words over the lobus pyramidalis, as Gruber (5), Kadyi (6), and Zuckerkandl (7) have given very detailed accounts of the same. Gruber (5) observes:—"The middle lobe is rarely glandular up to its termination at the os hyoideum, where it is fixed either immediately or by means of a short ligament. As a rule, it was as a flat narrow ligament, which attaches itself to the lower margin or the posterior surface of the body of the hyoid bone." All the cases examined bear out these statements.

Though a large number of lobi pyramidales were examined microscopically, *I have never been fortunate enough to find anything like a duct in the same.* Herein my results differ from those of His and Mr Sutton. In each instance the cornu medium consisted of thyreoid gland tissue, which at times was poorly developed. Often it contained much striped muscular tissue, or was entirely made up of such.

The *glandulæ supra- and præhyoideæ*, which are not uncommon, are always situated at the *anterior and upper surfaces* of the basi-hyoid, and are thus separated by the diaphragma oris and the hyoid bone from the plane of the cornu medium, or rather of its insertion (*cf.* Kadyi (6)). The supra-hyoid glands are often found between the genio-hyoid muscles and hidden by them.

The *foramen cæcum* is by no means so constantly found as one is led to believe. In some cases no trace of it exists. The best marked foramina have been found in cases where the lingual tonsil was greatly hypertrophied, but whether there is a causal connection between these two conditions must remain doubtful for the present. The longest distance the probe could be passed into the foramen was 1 cm. In all cases the foramen, or we should rather say "canal," passed backwards comparatively superficially, and never showed any tendency to dip into the depth towards the basi-hyoid. His, on the other hand, mentions instances where the foramen cæcum is prolonged as a canal 2½ cm. in length, leading to the os hyoideum. Victor Bochdaleck (8), who gives a careful description of this canal, traces it under the dorsum of the base of the tongue, near the surface, as far as the ligamentum glosso-epiglotticum medium. He also refers to similar accounts in the works of older anatomists, *e.g.*, Morgagni, Vaten, and Heister.

His, in his work *Menschliche Embryonen*, gives a drawing, in which the cornu medium extends upwards as far as the basi-hyoid, and between the lingual muscles which have been separated is seen what appears to be a round cord. The latter, according to him, is the lingual duct. Now (1) the cornu medium and this lingual duct are separated by the hyoid bone; (2) as the round cord was not examined microscopically, it may justly be questioned whether it really is a duct. For on carefully separating the genio-hyoidei and genio-hyoglossi, a cord-like mass may in almost all cases be observed in the middle line between these muscles. I have repeatedly examined this cord-like mass microscopically, and in no instance found the slightest approach to a duct, or to thyreoid gland tissue, but simply fat and fibrous tissue. I therefore regard such cases and drawings with some doubt, unless a careful histological examination has been made.

To sum up, then:—*In* 100 *adults a ductus lingualis has never been found, in many cases not even a foramen cæcum. Whenever the latter was prolonged backwards any distance, it ran as a blind canal near the surface. A tubular lumen in the lobus pyramidalis was not observed.*

Results of the Examination of Fœtal and Infantile Tongues.

a. It was proved beyond all doubt, that a cornu medium and a foramen cæcum need not and do not go hand in hand.

b. Again, a tubular lumen was never found in the lobus pyramidalis which always consisted of muscular or thyreoid gland tissue.

c. The foramen cæcum was absent or exceedingly small in a great number of cases. The longest canal measured 5 mm. (in a new-born child), and ran close below the surface. In no case could the canal be traced to the hyoid bone, though in all these cases the microscope was employed. We come therefore to conclusions similar to those derived from the examination of adults. They are more valuable, however, as in all cases the microtome and microscope were used, and every section of a large series was examined.

The Histology of the Foramen Cæcum.

The foramen with its saccular prolongation is lined by squamous epithelium of the same nature as that of the buccal cavity. Externally to this is a layer of fibrous tissue. In and around the latter adenoid tissue is found, especially in cases where the lingual tonsil is hypertrophied. In fœtuses and infants this adenoid tissue was never seen, so that it is apparently a morbid change. Columnar or ciliated epithelium was never found. All around the foramen and its canal, in most cases, numerous tubular racemose glands were seen, and they often opened into the lumen of the canal. These glands are of the same nature as the ordinary lingual muciparous glands. Their number varies considerably, for in some cases none are found in the depth below the foramen. But in most cases a group is seen in the middle line, some distance below the foramen, and these open by means of long ducts into the foramen, or on the surface. These glands form a deep central or septal

group, and are situated just above the central septum of the tongue.

Conclusions as to the Origin of the Foramen Cæcum.

From all these considerations this conclusion must be drawn, that no intrinsic connection exists between the development of the tongue and that of the thyreoid gland. This shall now be further elucidated by embryological deductions. The thyreoid gland is developed, as was mentioned above, from an outgrowth of the pharynx in the neighbourhood of the second branchial arch. Soon afterwards, two nodules appear in the middle line in the same region. These two nodules (which eventually become the base of the tongue) soon blend and then form a kind of a lid to the thyreoid outgrowth. Finally, these fused nodules join with the *tuberculum impar*, and at the point of junction the foramen cæcum is found. The latter is therefore more ventrally situated than the thyreoid outgrowth, and can only so far be said to have any connection with the thyreoid duct, as both are derived from the pharyngeal wall. A communication between the two can only exist if the two nodules do not join. In the meantime, the nucleus for the hyoid bone appears, and forms, so to say, a partition between the two. These considerations, coupled with an extensive anatomical examination, have convinced me at least, that though the foramen cæcum and the thyreoid duct are both developed from the pharynx, they are quite distinct one from the other. And when a tumour composed of thyreoid tissue is actually found in the base of the tongue, I should hesitate to trace its origin to the so-called lingual duct.

Pathological Questions in Connection with the Lingual Duct.

Mr Bland Sutton (3) describes tumours at the base of the tongue, which histologically are made up of thyreoid gland tissue, and according to him genetically also must be considered as such, being derived from His's thyreo-glossal duct. As far as my own observations go, I must doubt these statements. And if the tumours described be really thyreoid glands I can only conceive *one mode* of development. In the neigh-

bourhood of the os hyoideum, as Kadyi (6), Gruber (5), and others have shown, accessory thyreoid glands, viz., glandulæ supra- and præhyoideæ, are not unfrequently found. They are situated on the upper and anterior surfaces of the bone, and sometimes are of such size that one has to separate the genio-hyoid muscles to dissect them out. Now it is not difficult to imagine that one of these glandulæ hyoideæ might hypertrophy and eventually cause a bulging on the dorsum of the tongue.

It is, however, doubtful whether most of the cases described by Mr Sutton are histologically made up of thyreoid gland tissue. Looking into the cases, we find :—

1. Rushton Parker's case (9) was certainly a *tubular* adenoma. His description is altogether unambiguous.
2. Hickman's tumour (10), according to the verdict of the Morbid Growths' Committee, was "the result of hypertrophy or excessive development of the racemose glandular structures at the base of the tongue."
3. Mr Butlin showed two tumours at the Clinical Society (April 1890). These were both situated in the base of the tongue in the middle line. He thought they might possibly be of the nature of thyreoid glands. Mr Bowlby, an authority of great weight, offered strong opposition to this view. I have seen the microscopic specimens of these tumours, and do not hesitate to agree with Mr Bowlby that they are instances of *tubular glandular* adenomata.

Lastly, there are two cases described by Bernays (12), and Wolf (4). I have not been able to obtain the former's paper, but, as far as I can judge from the drawings reproduced by Mr Sutton (3) in his lectures on "Tubulo-Dermoids," I am inclined to consider it a case of hypertrophied accessory thyreoid gland (glandula hyoidea). Wolf's tumour, according to E. Fränkel, was apparently made up of elements resembling thyreoid gland tissue in a state of cystic degeneration. The anatomical description is very imperfect, but we may gather from the meagre account, that (*a*) its base was deeply seated amongst the muscles of the tongue, (*b*) it was *not central*. Hence, with Wolf, I am inclined to regard the tumour as an enlarged glandula thyreoidea accessoria hyoidea.

The mucous glands at the base of the tongue are very prone

to cyst-formation, as may best be seen in cases where the lingual tonsil is in a state of chronic hypertrophy. At times cysts are noticed which may be seen with the naked eye. I have come across three such cases. In one of these the cysts were due to glandular disease, as a glance at the drawing will show (*v.* fig. 1.) This tongue was removed from a still-born child, and on cutting into it minute cysts were found at the base of the tongue. One of the cysts, larger than the rest, was situated in the middle line. There were neither foramen cæcum nor lobus pyramidalis present. In the second case, the cystic appearance was due to the presence of typical cavernous lymphangiectasis; while in the third case the cyst, which was situated deeply between the genio-hyoglossi muscles, was apparently bursal in character.

I believe, therefore, that most of the cases of tumours in the base of the tongue described are *tubular glandular adenomata*, derived from the mucous glands situated there, and that if thyreoid gland tissue should be found, it is developed from the glandulæ hyoideæ, and has nothing to do with the foramen cæcum and its blind cul-de-sac-like prolongation.

"*Persistent Lingual Ducts.*"

Lastly, those cases require consideration which either have been described as persistent lingual ducts, or which, being central fistulæ opening at the base of the tongue, might be described as such. Mr Raymond Johnson (14) has lately brought forward two such cases under the title of "persistent lingual ducts." The following cases are all instances of central, complete, or blind congenital fistulæ. Out of a long list, for which I am indebted to an excellent paper by K. v. Kostanecki and A. v. Mielecki (23), only those have been chosen which occupied part of the course ascribed by His to the thyreo-glossal duct. For fuller details I must refer to the paper of the joint authors and to their original articles. Cases have been described by Larrey (15), Heusinger (16), Faucon (17), Houel (18), Affre (19), Berkeley Hill (20), Trélat (21), and Volkenrath (22).

I fully agree with Kostanecki and Mielecki, whose paper should be consulted in connection with this subject, that all these fistulæ are due (*a*) to a deficient closure of the *sinus*

cervicalis of Rabl (24) and His (2), (*b*) to a persistence of the second inner branchial groove which has torn through into the sinus cervicalis. Mr Johnson's case must also be considered in the light of a fistula.

It may not be out of place shortly to refer to the development of the sinus cervicalis. The branchial arches are separated from one another by what used to be called the branchial clefts. The researches of His, Born (25), and Kölliker (20) have shown that these clefts do not exist in human embryos, but that the arches are separated by grooves. These grooves may be seen on the outer surface as well as on the inner surface, so that we have inner and outer grooves separated from one another by a thin closing membrane (*v.* fig. 2). According to His and others this closing membrane remains intact. After the fourth week we have a displacement of the four branchial arches, the first two growing quicker than the third and fourth. Viewed from without, the fourth arch is overlapped by the third, the third by the second, and so on; while on the inner aspect the fourth arch overlaps the third, and this, again, the second. In this manner the sinus cervicalis is formed (fig 3). In its depth and anteriorly the third and fourth arch would be found, while its entrance is bounded anteriorly by the second or hyoid arch (fig. 3). The sinus is eventually closed by (*a*) the two opercular processes, which grow backwards and towards the middle line from the hyoid arches; (*b*) the retrobranchial processes; and (*c*) in part by the thoracic wall which arches over the sinus. For full details reference should be made to His's (2) and Rabl's works (24).

We thus see that, should the sinus cervicalis remain patent on account of an incomplete closure by the two opercular processes which converge from each side towards the middle line, a canal is formed which runs upwards towards the first and second arches. Should now an inner groove, on account of a tear through its closing membrane, communicate with the unobliterated sinus, a complete mesial fistula is the result. *Obviously it is only the second inner groove which can tear into the sinus.*

As the tongue is developed exclusively from the second arch, it becomes at once evident how a blind or complete fistula may

extend into its base, where it then most likely opens at the foramen cæcum.

While this study was undertaken, Kostanecki's and Mielecki's paper (23) appeared, and with great pleasure I acknowledge my indebtedness to them, at the same time referring all pathologists and anatomists interested in the subject of branchial fistulæ to their careful investigations.

In fine, I hope to have shown that the so-called lingual duct and the glandular tumours at the base of the tongue are not derived from a thyreo-glossal duct, but have an origin quite distinct from that of the thyreoid gland.

EXPLANATION OF PLATE III.

All the drawings have been made by Mr Morrison, a student at St Bartholomew's Hospital. I take this opportnnity of thanking him for his kind help.

Fig. 1. Cysts at base of tongue due to glandular disease.

Fig. 1*a*. Coronal section through foramen cæcum. In this case the canal of the foramen was 5 mm. long. A duct of one of the stationary glands is seen to open into the "foramen." *f.c.*, canal of the foramen cæcum.

Fig. 2. To show the branchial arches with the closing membranes, stretching from arch to arch. Shows also the inner and outer grooves; *b.a.*^{1}, &c., branchial arches; *c.m.*, closing membrane.

Fig. 3. To show the anatomy of the sinus cervicalis. *s.c.*, sinus cervicalis; *b.a.*^{2}, 2nd branchial arch.

LITERATURE.

1. KASTSCHENKO, *Archiv f. mikrosk. Anat.*, vol. xxx.
2. HIS, *Anatomie menschl. Embryonen; Archiv f. Anat. and Physiol.*, 1881; *Archiv f. Anat. and Physiol.*, 1889; *Anat. Anzeiger*, 1886.
3. BLAND SUTTON, "Lectures on Evolution in Pathology," *Illustr. Med. News*, vol iii.
4. RUDOLF WOLF, *Langenbeck's Archiv*, 1889, vol. xxxix. p. 224.
5. GRUBER, *Virchow's Archiv*, lxvi. p. 447; lxxviii.
6. H. KADYI, *Archiv für Anat. and Physiol.*, 1879.
7. ZUCKERKANDL, quoted by Müller in *Archiv für. Anat. and Physiol.*, 1879.
8. VICTOR BOCHDALECK, *Archiv f. Anat. and Physiol.*, 1867, p. 775.

9. Rushton Parker, *Trans. Path. Soc.*, xxxii. p. 238.
10. Hickman, *Trans. Path. Soc.*, xx. p. 168.
11. H. T. Butlin, *Clinical Society*, April 1890.
12. Bernays, quoted by Bland Sutton, (*v.* 3).
13. O Hertwig, *Lehrb. d. Entwickelungsgesch.*
14. R. Johnson, "Path. Society," *Lancet*, May 10, 1890.
15. Larrey, *Bulletin de Soc. de Chirurgie*, 1852-53, vol. iii. pp. 489, 503, 607.
16. Heusinger, *Virchow's Archiv*, xxix.
17. Faucon, *Gaz. des hôpitaux*, 1874.
18. Houel, *Ibid.*, p. 491.
19. Affre, *Thèse de Paris*, 1875.
20. Berkeley Hill, *Lancet*, 1877; ii. p. 842.
21. Trélat, *Thèse de Paris*, by Guzman, 1886.
22. Volkenrath, *Inaug. Diss.*, Bonn, 1888.
23. K. v. Kostanecki and A. v. Mielecki, *Virchow's Archiv*, vols. 120 and 121.
24. Rabl, *Prager. med. Wochenschr.*, 1886, 1887.
His, *Archiv f. Anat. and Physiol.*, 1886, pp. 421, 428.
25. Born. *Archiv f. mikrosk. Anat.*, vol. xxii.
26. Kölliker, *Entwickelungsgesch. d. Menschen*, &c.; *Grundriss d. Entwickelungsgesch.*

NOTES ON THE ORIGIN OF THE LIVER. By THOMAS W. SHORE, M.D., B.Sc., *Lecturer on Comparative Anatomy at St Bartholomew's Medical School.* (PLATE IV.)

(From the Biological Department of St Bartholomew's Hospital.)

A. *Preliminary.*

IN many invertebrates there is found in connection with the mesenteron an organ which has received the name of "liver;" in others, some of the endodermal lining cells of the gut are different from the rest, and have been regarded as "hepatic." It is much open to question whether any of these structures are either physiologically or morphologically equivalent to the organ known as liver in the Vertebrata. It is best, for the present, to speak of these structures as the "glands of the mid-gut," or "glands of the mesenteron." An investigation of these "glands of the mesenteron," with a view to determine their relationships to the liver of vertebrates, is one which may lead to important results. Such a research may be made from (*a*) the physiological side, or (*b*) the morphological. An inquiry from the latter point of view will include—(1) an examination of the structure of the liver of as many types of vertebrates as possible, and the small liver of lower forms particularly should be investigated, so as to learn in its simplest condition the plan of structure of the organ in this large group; (2) a comparison of this structure with that of the "glands of the mesenteron" in as large a number of diversified types of invertebrates as possible; (3) a study of the ontogeny of the liver of Vertebrata; (4) a comparison of the facts thus learnt, with the development of the glands of the mesenteron in invertebrates.

From the nature of the secretion produced by the so-called "livers" of invertebrates, and from the digestive actions of these secretions, some observers have classed these organs as "pancreatic" rather than "hepatic." Writing on the intestine of Decapods and its gland, Cattaneo[1] finds that the gland of

[1] *Atti. Soc. Ital. Sci. Nat.*, xxx., 1887, p. 238.

Fig. 1.

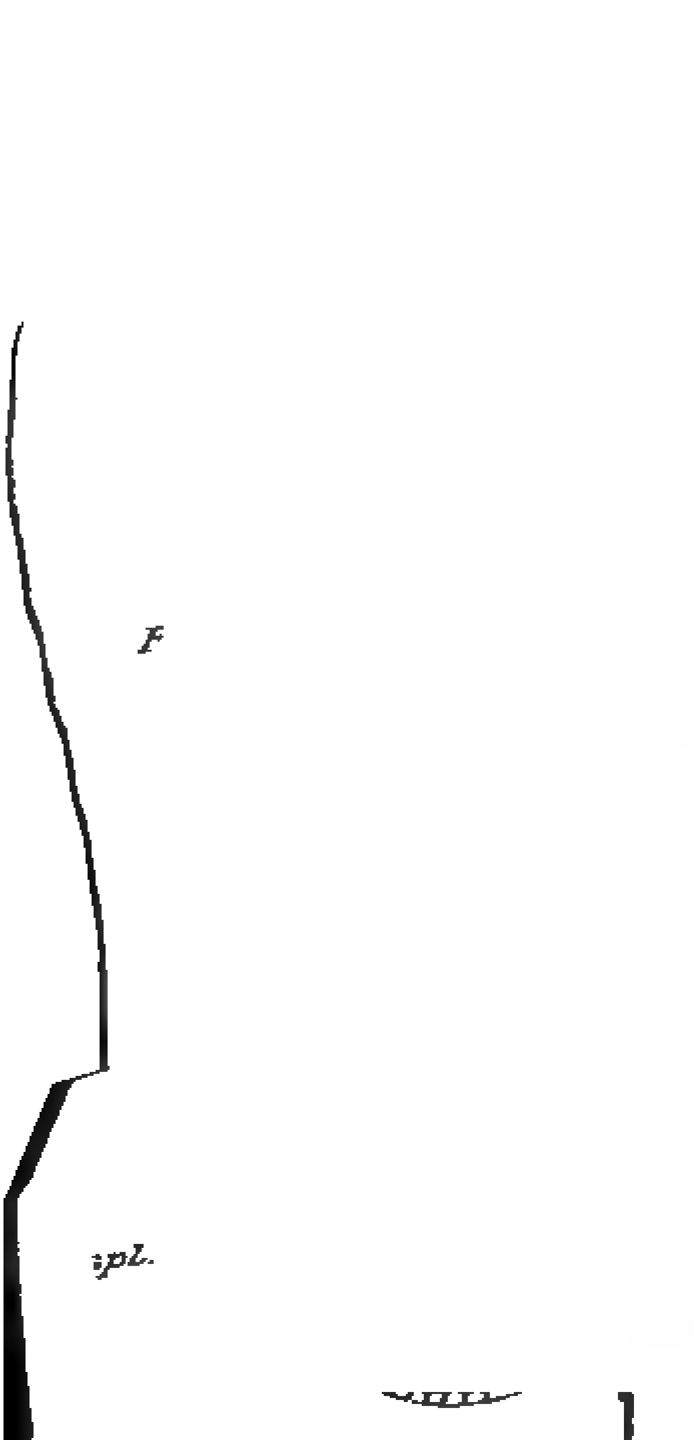


Fig. 11.

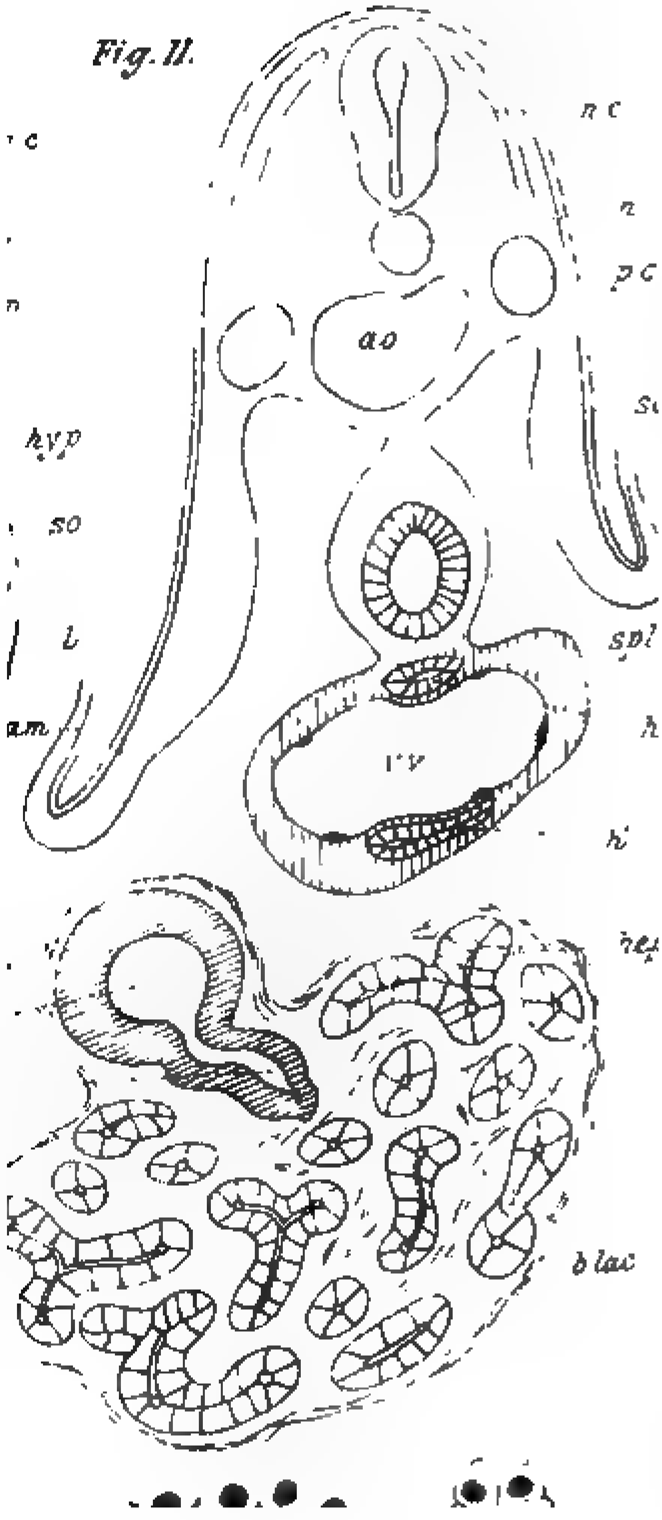
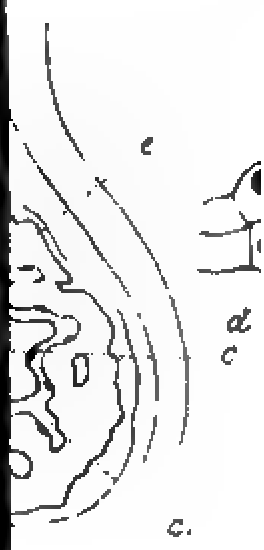


Fig. 14.

Fig. 1



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the mid-gut or "liver" is complex enough, in function, to be compared to that of all the vertebrate's digestive glands together—in other words, he finds it to be "poly-enzymatic." By some it has been called "hepato-pancreas." A. B. Griffiths[1] finds that the "liver" of *Carcinus mœnas* is in function pancreatic. He also concludes that the secretion of the so-called "hepatic cells" in Araneina[2] is similar to the pancreatic fluid of Vertebrata both in function and in chemical nature.

In July 1889, I published, in conjunction with my colleague, Dr Lewis Jones,[3] an account of the minute structure of the liver of a large number of vertebrated types, but particularly with the object in view of explaining some doubtful points as to the liver of mammals, and of showing the relation between the well-known tubular liver of lower vertebrates, and the apparently parenchymatous arrangement found in this organ in the mammal. In this paper we showed that the liver of all the vertebrates examined is built up on the same plan, and that in all cases the organ is a tubular gland, but one having a special and unique feature, not found in any of the ordinary tubular glands, such as the pancreas or salivary glands. The vertebrate's liver is in every case composed of an anastomosing network of cylinders of cells. These cells are arranged in a single layer, so as to form the boundary walls of a network of anastomosing "secretion channels" of minute calibre, a secretion channel penetrating the axis of each cell-cylinder, branching with it and following its anastomoses. The number of cells seen in a cross section of one of these cylinders, and disposed around the central lumen, varies from two to six, being generally more numerous in the livers of lower types. The meshes of the network formed by the branching and anastomosis of these cylinders are in some cases broad, in others narrow, varying as the meshwork of secretion tubes is loose or close. These meshes are occupied by blood "capillaries," having walls composed of a single layer of flattened nucleated epithelial cells, and which are themselves arranged as a network. Each mesh of the blood-capillary system is thus occupied by a secretion tube, as each loop in the system

[1] *Proc. Roy. Soc. Edin.*, xvi., 1888–9, p. 178.
[2] *Proc. Roy. Soc. Edin.*, xv., 1887–8, p. 111.
[3] *Journal of Physiology*, vol. x., No. 5, p. 408, 1889.

of secretion cylinders is filled by a blood capillary. There is a further characteristic feature in the liver structure as compared with that of an ordinary tubular gland, which is of very great importance. The cells forming the walls of the secretion tubes *are not surrounded by any basement membrane* at all comparable to the layer so named in the case of a compound tubular gland of the ordinary type. The external surfaces of the liver cells are therefore in contact with the thin walls of the blood capillaries, and every proper secretion cell has on one side of it a blood channel with a definite wall, and on the other a secretion channel. Although this arrangement is not very obvious in the livers of the higher vertebrates, it can nevertheless, in a properly prepared section, be made out. A section of one of the livers in which the structure above summarised is most obvious, presents an appearance at first sight very like that of a section of a salivary gland; a little examination, however, will show the following two important features of difference:—(1) *That in the liver the secretion tubes form an anastomosing network;* (2) *that no basement membrane is present. In no vertebrated animal which I have examined is there to be found a tubular structure without anastomosis.*

Although the general plan of structure of the liver is the same in all the Vertebrata, there are, of course, differences between the various types examined. These differences seem to be (*a*) differences of degree of penetration of blood-vessels amongst the cell-cylinders; (*b*) differences in the density of the network of liver tubes; (*c*) differences as to the number of rows of cells to form the walls of the secretion channels; (*d*) the presence in mammals of lobules, which have probably arisen by a tendency for blood capillaries to arrange themselves around foci of exit for blood; (*e*) the relative number of fine ducts in the liver substance depending upon the degree to which the bile duct has extended within the organ; (*f*) the relative amount of connective tissue extending along the course of the bill ducts and portal vein branches, so as to form a definite Glisson's capsule.

An anastomosing network of the kind here briefly described can only have arisen in one of two ways—(*a*) by the union together of the extremities of originally distinct tubes; (*b*) by

the subdivision of an originally solid mass of cells, owing to the development within it of a network of intercellular spaces. For reasons which I have detailed and discussed in the *Journal of Physiology*, I and my colleague have put forward the latter hypothesis. On this theory the liver of the Vertebrata is believed to have been evolved by some such steps as the following[1]:—

"1. The formation from the gut of a hollow diverticulum constituting at first a simple tubular gland, lined by specially modified secreting endoderm. This stage is represented in actual anatomy by the simple hepatic diverticulum of the *Amphioxus*, and is reproduced in the ontogeny of the higher vertebrates by the formation of the primary hepatic outgrowth of the hypoblast, as in the Chick, &c.

"2. The copious subdivision of the endoderm cells at the cæcal extremity of this diverticulum to form a solid mass of cells, slightly penetrated by minute channels for escape of secretion, the original diverticulum becoming a duct.

"3. The further multiplication of the cells of this mass, and its penetration by blood-vessels, so as imperfectly to divide it into solid anastomosing rods of secreting cells drained by a system of intercellular bile canals. This step is probably preserved in the liver of the lamprey.

"4. The more complete penetration of blood-vessels between the cylinders of hepatic cells so as to form a well-marked system of broad blood channels, separating a network of rods of cells which come to be arranged in a single layer around bile capillaries. This is seen in the permanent condition of fishes, amphibians, and reptiles, and is ontogenetically repeated in the development of the mammal.

"5. A still finer penetration by blood-vessels and further subdivision of the hepatic cylinders, associated with an arrangement of the blood capillaries around foci of exit for blood, so as to form hepatic lobules. This is the condition found in the adult Mammalia."

It will be at once seen that this view of the evolution of the vertebrate's liver implies that the organ has arisen within the limits of the group *Vertebrata*, and that the structures supposed to be of "hepatic" nature in invertebrates have no connection with it, and are not phylogenetically related to it. In putting forward this view, I and my colleague were guided almost entirely by the facts we learn from an examination of the structure of the liver of adult vertebrates. It is clear, however, that the conclusions must be tested by an investigation of the "hepatic" organs of invertebrates, and by a study of the ontogeny of the organs which are named "liver" in both

[1] Quoted from the *Journal of Physiology*, vol. x. p. 425.

vertebrates and invertebrates. I have begun a research on this question, using ordinary histological methods. My material is chiefly hardened in some chromium preparation, or in picric acid, or in alcohol; this is followed by staining in bulk, embedding in paraffin, and cutting with the rocking microtome. In some cases I fail to obtain good results by these methods; and have found fixing in osmic acid to be very useful in some cases. In studying the ontogeny of the liver I have at present worked chiefly with frog, chick, and rabbit embryos, ordinary embryological methods being employed. Most of my sections are about 10μ in thickness. Some points of interest have already arisen in my work, and these form the subject of the present notes. I will first briefly describe the structure of the "gland of the mesenteron," in a few typical invertebrates, and after indicating some points on the development of the liver in vertebrates, will discuss the conclusions which the facts published in the *Journal of Physiology*, together with those now described, seem to indicate.

B. *Structure of the "Liver" of some Invertebrata.*

1. *Mollusca.*—In this phylum there is almost always present some appendage or appendages of the mesenteron, to which the term "liver" has been applied. They take the form of more or less wide sacculi or outgrowths from the endoderm of the gut, which, becoming drawn out and subdivided, form a number of cæcal acini. These may be grouped into larger or smaller lobes, held together by connective tissue, so as to form, in some cases, organs of considerable magnitude. In most of the *Lamellibranchiata* the gland of the mesenteron is well developed, forming a number of lobes opening into the "stomach" by several wide pouches or ducts. In the most typical of the *Gasteropoda*, it is a largely developed organ, occupying a considerable portion of the visceral dome; it surrounds the coils of the intestine, is arranged into lobes, and opens by one or more ducts into either the intestine or the "gastric" enlargement. In some Mollusca, viz., the so-called *Nudibranchiata*, the glands of the mesenteron consist of large metamerically repeated pairs of tube-like diverticula of the gut, from which numerous glandular outgrowths are given off; and

in some cases these diverticula send cæcal prolongations into the cirrhus-like processes of the dorsal integument—a fact which suggests that they may have some function other than that of secretion of a digestive fluid. Fol,[1] in describing the microscopic anatomy of *Dentalium*, states that the "liver" is a collection of cæca, which open into the stomach. The cæca of the "liver" are lined by an epithelium widely differing from that of the stomach, though a transition from the one to the other is found, so that it is difficult to mark the boundary between stomach and liver duct. The protoplasm of the "hepatic" cells has a spongy nature, and in sections appears to be honey-combed into a number of large spaces. The cells are described as narrow and rather elongated.

The "liver" of *Mya arenaria* is seen microscopically to be composed of a large number of wide cæca, mostly oval or rounded in form, and grouped together upon branches of broad diverticula from the stomach. These cæca are loosely bound together by connective tissue into lobes, and their general features, as seen in a section, are shown in Plate IV. fig. 1. Each ultimate pouch or cæcum is formed of—(*a*) a wall of condensed connective tissue, containing small oval nuclei, *i.e.*, a basement membrane, continuous with the similar membrane upon which the epithelial cells lining the stomach are placed; (*b*) a layer of much modified epithelial cells continuous with those of the general endoderm. The protoplasm of these cells is dense, and stains readily near the basement membrane; but more towards the centres of the cæca the protoplasm of the cells seems to be confluent into a general network of finely granular fibrils, anastomosing around large clear spaces, which are gradually lost in the large central cavities of the cæca. The inner contours of the cells are therefore very indefinite, and their protoplasmic bodies are, in fact, deeply honey-combed, as is described by Fol, in *Dentalium*. The nuclei of the "liver-cells" are round, and lie in the deeply-stained denser peripheral protoplasm. Each nucleus contains a marked nucleolus. Groups of the ultimate pouches may readily be seen in sections uniting together into common larger sacculi, the walls and epithelium of which have the same characters as are

[1] *Arch. Zool. Expér. et Gen.*, vii., 1889, p. 91.

found in the ultimate pouches. The epithelium of the "liver" cæca is very different in character from that forming the endodermal lining of the stomach, the cells of which are elongated in form, and richly ciliated. By examination of sections with a low power it is clear that there is *no anastomosis between different cæca.*

In all essential particulars the gland of the mesenteron in *Anodonta cygnæa* agrees with that of *Mya.* There is no trace of any anastomosis of cæca with each other. The cells forming the proper secreting substance are planted upon a definite basement membrane, and are honey-combed in their central parts as in *Mya.* The "liver" of *Helix pomatia* is built up on the same plan as that of *Mya* and *Anodonta,* viz., isolated cæca, made up of a basement membrane, lined by honey-combed cells. The whole texture of the organ is, however, denser, and the outlines of the pouches are more irregular than in *Anodonta* and *Mya.* The "liver" cæca join the stomach and intestine at several points, and in a fortunate section the transition from the elongated columnar epithelium of the intestine to the honey-combed cells of the "liver" cæca may be traced along a short duct. In some cases in *Helix,* viz., in the "liver" of a hibernating animal, the spaces in the honey-combed part of the protoplasm are found to be occupied by rounded masses of a dark brown colour, and with a highly refractive appearance.

In *Limax hortensis,* as would be expected, the same general characters are found. The tissue is looser than in *Helix,* and the minute characters of the cells are somewhat different from those already described. The peripheral portions of the cells contain nuclei, and stain deeply, as in *Mya* and *Anodonta,* but the central portions are not deeply honey-combed. The inner margins of the cells immediately bounding the cavities of the cæca are, therefore, more definite. The whole of the central portions of the protoplasm, however, stain lightly, and are loaded with a dark brown granular substance. The nuclei of the cells are always large and distinct.

The characters of the "liver" in *Aplysia* are very similar to those of *Limax.* The same general plan as in other Mollusca is present. The outlines of the cells lining the cæca are definite,

and they are not honey-combed. The cells vary much in shape, but are mostly narrow and elongated, and are somewhat swollen at their free ends, having pyriform or rounded inner extremities.

2. *Arthropoda.*—In the great majority of the Crustacea, some sort of gland of the mesenteron is present. In most of the Entomostraca a pair of short rounded wide cæca are given off from the anterior part of the mid-gut. This is the case, for example, in *Daphnia* and *Lepas.* In these cases, the walls of the cæca do not appear to be very different from the rest of the lining of the mesenteron, though they are probably the first rudiments of what, in other cases, becomes a considerable gland. In some of the Entomostraca these cæca are branched and glandular in appearance, and in any case, whether branched or not, generally lie in the cephalic region. In the Hedrophthalmia division of the Malacostraca, cæca are found in connection with the anterior part of the mid-gut, as in the Entomostraca, but they are generally long unbranched tubes which pass backwards into the thoracic or abdominal regions. They are well formed in *Oniscus,* where each diverticulum is branched near its origin, so that we find two pairs of long glandular tubes. In *Gammarus,* a pair of similar tubes are found passing backwards beneath the gut. In the Schizopoda division of the Podophthalmia, similar long unbranched cæcal tubes are found. In the Decapoda, however, the cæca, though developed from the same part of the mesenteron, are much branched into a number of straight finger-like tubes loosely connected together, and grouped into lobes on the sides of branches of a pair of ducts, altogether forming a pair of large glandular organs. This is the case with the so-called "liver" of *Astacus, Carcinus, Homarus,* &c. In some of the Crustacea a pair of cæca given off from the anterior part of the mid-gut are not found, but in place of them functionally are a number of more or less metamerically arranged pairs of outgrowths from the rest of the mid-gut. In the Arachnida, there are frequently present one, two, three, or more pairs of tubular organs opening into the mid-gut, and bearing tufts of glandular cæca. (These must not be confounded with the pairs of gastric cæca found in spiders, and which are not formed from the mid-gut, nor with the Malpighian tubules developed more posteriorly, and which are

undoubtedly of "renal" nature.) In the Insecta "hepatic" diverticula are not frequently found, but the so-called "pyloric cæca," of such a type as *Periplaneta*, may be of this nature. The most highly developed of all the glands of the mid-gut amongst the Arthropoda is the "hepato-pancreas" or "liver" of the Decapoda, *e.g.*, *Astacus fluviatilis*, and a short description of it will suffice for the purposes of this paper. The "liver" of *Astacus* is well known as forming a pair of yellow coloured glands made up of several loose lobes lying at the sides of the gut, and posterior parts of the "stomach." They are composed of a large number of long processes grouped together on branches of the "hepatic" ducts. The whole texture of the gland is very loose, and the general arrangement of its structure can be well seen without microscopic assistance. On microscopic examination of sections, each finger-like process is found to be a cæcum, having a thin wall of connective tissue lined internally by a single layer of large cells. A section of one of the cæca is figured in Plate IV. fig. 2. The cells are narrow and elongated, and stain well. Their nuclei are found in the peripheral parts where the protoplasm is dense. More internally, the body of each cell is found to be much vacuolated, and its texture spongy, the protoplasm again becoming dense at the free inner borders of the cells, where a deeply stained band is found forming the immediate boundary of the large central cavity. The cells are particularly narrow at their bases where the nuclei lie, and are broader, with rounded margins, at their central free extremities. They are thus more or less club-shaped, and the border of the central cavity is in consequence not circular, but sinuous. When the extremity of one of the cæca has been cut longitudinally in the section, there is found to be a dense mass of deeply vacuolated cells completely filling up the cavity of the tube in this region.

On comparing the most highly developed "liver" of the Arthropoda with the most highly developed one of the Mollusca, there is a general agreement as to structure, and in the common feature of being markedly different from the liver of Vertebrata. The chief difference is in the form of the ultimate cæca or acini of the gland—in Mollusca they are rounded, short, and pouch-like, in Arthropoda, elongated and tube-shaped.

3. *Lower Groups.*—In the Vermes, generally speaking, separate glands are not developed in connection with the midgut. In some cases, however, the epithelium of this part of the alimentary canal is found to have a different character to that of the other parts of the tube. The cells in these cases are swollen, more granular, and have brownish or yellowish contents. In some of the Trematodes, *e.g.*, *Distomum*, and in Turbellarians, *e.g.*, *Planaria*, the mesenteron is thrown into cæcal branches, the cells lining which have more "glandular" characters than those forming the rest of the endoderm. The cæca of the intestine of *Distomum* are pouches or branched tubular outgrowths, and are composed of a thick basement membrane lined by a single layer of elongated cells, whose nuclei are placed at about their centres. The peripheral parts of the cells are striated longitudinally, and the central portions are softer, more irregular, and finely granular. These cæcal branches are probably secretory, and may be regarded as appendages differentiated for the purpose of producing a digestive fluid. In some Chætopods, we find the specially differentiated "hepatic" cells along the whole length of the intestine, as in *Lumbricus*. In some of the higher Chætopods, *e.g.*, *Aphrodita*, it is well known that the mesenteron gives off definite cæca, each terminated by what appears to be a secreting gland. These cæca are generally regarded as "hepatic." In the Rotifera, and again in some Polyzoa, the epithelium of the mesenteron has an appearance suggestive of secretory functions.

So far as my observations have at present extended, the so-called "liver" of invertebrated animals has in no case a structure at all comparable to that of a vertebrate. In the former, there is never present that anastomotic network of liver-cylinders or liver-tubules, which is so characteristic of the latter; nor is there to be found in the invertebrate any such penetration of the gland substance by a network of blood channels as is so striking a feature of the vertebrate liver. The secreting structures in the invertebrate's liver, on the contrary, are large cæcal branches or saccular dilatations of a duct, and have a relatively large cavity surrounded by definite walls formed of the secreting cells, *planted upon a basement membrane of connective tissue.* As far as my

researches extend, this is never the case in the liver of a vertebrate.

We are thus led to conclude—*that the "liver" of Invertebrata differs fundamentally in structure from that of Vertebrata;* (a) *in the absence of an anastomosing system of secretion tubules arranged so as to form a network;* (b) *in the absence of any co-existing network of blood-vessels;* (c) *in being composed of cæcal dilatations of a duct, consisting of secreting cells arranged around large central cavities; and* (d) *in the presence of a basement membrane around the cells.*

This conclusion being granted, we next have to inquire whether the vertebrate's liver has been evolved from one of the invertebrate type. It can only be conceived possible for this to have occurred if it be granted that union together of the cæcal extremities of originally distinct tubules, so as to form an anastomosing network, can take place. If this is allowed, it is easy to understand how, by repeated branching, and by the recurrence of anastomosis at the ends of contiguous branches, a network of any degree of fineness may have arisen. I find it difficult, however, to believe that this has been the case, partly on account of the presence of a basement membrane in the invertebrate's liver, and its absence in that of vertebrates, and partly for reasons which Lewis Jones and I have indicated in our paper in the *Journal of Physiology*, to which the reader is referred.

We must, therefore, in the present state of our knowledge, conclude that the liver of Vertebrata *has not been evolved from that of any known invertebrate type, and must therefore have arisen within the limits of the vertebrate phylum itself.*

This conclusion is supported by the fact that no transitional conditions between the two kinds of "livers" are known. It is also strengthened by the consideration that in the development of the vertebrate liver no condition is found at any stage which could properly be compared to the liver of any invertebrate. Moreover, during its development, in the Chick for example, it is not proved that the original cell cylinders are ever without anastomosis, though this is generally said to be the case. As a further point tending to uphold this conclusion, is the fact that the functions performed by the "liver" in the two cases are, as

far as we know, widely different—that of vertebrates seldom, if ever, secretes a digestive fluid *containing a ferment*, whilst that of the invertebrate is known, in several cases, to be "polyenzymatic."

All the facts of the case, then, tend to show that the summary of the stages in the evolution of the vertebrate liver, which is quoted at page 169 of this paper, is, in the present state of our knowledge, correct. Having thus concluded that the vertebrate liver was evolved within the limits of the vertebrate phylum we next have to inquire: In relation to the performance of what function was the vertebrate liver evolved? What circumstances led to its origin? The first step in this inquiry is a study of the actual development of the liver in Vertebrata.

C. *Development of the Liver of some Vertebrated Types.*

Before entering upon a description of my own observations on this part of the subject, it will be well if I briefly allude to what is currently taught, and to some of the points which others have described as the development of this organ in vertebrates.

In Elasmobranch fishes, Balfour[1] found that the middle part of the gut remains till late in embryonic life in connection with the yolk sack by the vitelline canal, which canal opens into the gut *immediately behind* the entrance of the hepatic duct. As to the relations of the blood-vessels to the developing liver, Balfour[2] says—"On the formation of the liver the proximal end of the subintestinal vein becomes the portal vein, and it is joined as it enters the liver by the venous trunk from the yolk sack."

The formation of the gut in the Teleostei is not very well known, and the origin of the liver in them is therefore somewhat obscure. Balfour[3] found that "in the just-hatched larva of an undetermined fresh-water fish, with a very small yolk sack, the yolk extended along the ventral side of the embryo from almost the mouth to the end of the gut. The gut had, except in the hinder part, the form of a solid cord resting in a concavity of the yolk. In the hinder part of the gut a lumen was present, and below this part the amount of yolk was small."[4]

[1] *Comparative Embryology*, 1st ed., vol. ii. p. 45.

[2] *Ibid.*, vol. ii. p. 53.

[3] *Ibid.*, vol. ii. p. 61.

[4] I shall endeavour to show in the sequel what importance is to be attached to these facts.

As to the development of the liver in Teleostei, Balfour[1] says:—
"The liver in the earliest stage in which I have met with it in the trout (twenty-seven days after impregnation) is a solid ventral diverticulum of the intestine which in the region of the liver is itself without a lumen." Referring to the relation of the liver duct to the yolk sack, Von Baër states that the yolk sack remains "in communication with the intestine immediately behind the liver," whilst on the other hand Lereboullet[2] finds "that there is a vitelline pellicle opening *between the stomach and the liver,* which persists until the absorption of the yolk sack." The relations of the liver to blood-vessels in Teleosteans also appear to be interesting. Rathke[3] and Lereboullet[4] say that the subintestinal vein at first *breaks up into lacunæ of the yolk sack, from which the blood is carried direct to the heart.* Later on, when the liver is developed, the subintestinal vessel breaks up into capillaries in this organ, thence passes to the yolk sack, and then to the heart. They also find that an artery is given off from the aorta, penetrates the liver and there breaks up into capillaries continuous with those of the yolk sack.

In the course of the development of the Cyclostomi, the alimentary canal immediately behind the stomach "dilates considerably and on the ventral side is placed the opening of a single large sack, which forms the commencement of the liver. The walls of the hepatic sack are posteriorly united to the yolk cells." The subsequent history of this hepatic sack is thus summarised by Balfour:—"The primitive hepatic diverticulum rapidly sprouts out and forms a tubular gland. The opening into the duodenum changes from a ventral to a lateral or even dorsal position. The duct leads into a gall bladder imbedded in the substance of the liver. Ventrally the liver is united with the abdominal wall, but laterally passages are left by which the pericardial and body-cavities continue to communicate." The subintestinal vein in Cylostomi has the same relations to the liver as are found in Elasmobranchs.

In the Ganoids, the relations of the liver, stomach, and yolk sack are very different from those found in other fishes. Balfour[5] says—
"In most Vertebrata the yolk cells form a protuberance of the part of the alimentary canal immediately behind the duodenum. The yolk may either, as in the Lamprey or Frog, form a simple thickening of the alimentary wall in this region or it may constitute a well-developed yolk sack, as in Elasmobranchs and the Amniota. In either case, the liver is placed *in front* of the yolk. In the Sturgeon, on the contrary, the yolk is placed almost entirely *in front of the liver,* and the Sturgeon appears to be also peculiar in that the yolk, instead of constituting an appendage of the alimentary tract, *is completely enclosed in a dilated portion of the tract, which becomes the stomach* . . . . .

[1] *Op. cit.*, vol. ii. p. 63.
[2] Quoted from Balfour, *op. cit.*, vol. ii. p. 65.
[3] For reference *vide* Balfour, *op. cit.*, vol. ii. p. 67.
[4] For reference *vide* Balfour, *op. cit.*, vol. ii. p. 66.
[5] *Op. cit.*, vol. ii. p. 90.

Behind the stomach is placed the liver. The subintestinal vein bringing back the blood to the liver appears to have the same course as in the Teleostei, in that the blood after passing through the liver is distributed to the walls of the stomach (*i.e.*, the yolk), and is again collected into a venous trunk which falls into the sinus venosus. As the yolk becomes absorbed, the liver grows forwards underneath the stomach, till it comes in close contact with the heart." On the other hand, in *Lepidosteus* there is a large yolk sack opening by a narrow vitelline duct into the intestine, immediately behind the liver.

In the Amphibia, the liver begins as a ventral diverticulum of the gut immediately in front of the yolk.

It is generally taught that the first rudiment of the liver in the Amniota, consists of one or two ventral diverticula from the gut, one or both of which grow into a special thickening of the splanchnic mesoblast. "From [1] the primitive diverticula there are soon given off a number of hollow buds which rapidly increase in length and number and form the so-called hepatic cylinders. They soon anastomose and unite together and so constitute an irregular network. Coincidently with the formation of the hepatic network, the united vitelline and visceral vein or veins in their passage through the liver give off numerous branches, and gradually break up into a plexus of channels which form a secondary network amongst the hepatic cylinders."

1. *Development of the Liver in the Frog.*—The early stages in the formation of that part of the gut from which the liver develops must first be briefly described. At the close of segmentation, the frog's ovum consists of two unequal parts, viz., a mass of small epiblastic cells at one pole, and an accumulation of larger or yolk cells at the other pole, with a segmentation cavity between them. At an early stage, the epiblastic cells begin to extend on all sides around the yolk cells, so that the line of junction of the two kinds of cells seen on the surface of the sphere gradually becomes nearer and nearer to the yolk-pole. Very soon, there takes place on that side of the ovum, which will subsequently become the dorsal, an inflection of the epiblast cells along a small arc of the epiblastic margin. This is the commencement of an asymmetrical invagination. The cells which thus become inflected are soon found, on examining a section, to form two strata: (*a*) a single layer of hypoblast; (*b*) several layers of mesoblast-cells lying between the superficial epiblast and the deepest stratum of the inflected cells. Gradually, as the epiblast grows more and more

[1] Balfour, *op. cit.*, vol. ii. p. 632.

over the yolk cells, the extent of the arc of inflection becomes greater till the whole of the epiblastic margin is inflected. The circle representing this involuted margin is the blastopore, which, so far as my observations extend, appears subsequently to become the anus.[1] The proportion of the hypoblastic layer which is formed from the epiblastic cells actually inflected is small, the greater part of it being produced by a transformation of yolk cells into hypoblast in a line with those cells which are actually invaginated. This transformation of yolk cells into hypoblast extends most rapidly along what will be the dorsal wall of the gut. Meanwhile, a cavity (the mesenteron) has been formed between the extending hypoblast and the underlying yolk cells. In a short time, the hypoblast extends laterally, in what will form the anterior part of the embryo, so that this part of the mesenteron gradually becomes completely surrounded with a true hypoblastic epithelium. This lateral extension of the hypoblast is solely due to a transformation of yolk cells. The cavity of the mesenteron becomes similarly completed posteriorly, but in its middle regions the lateral transformation of the yolk into hypoblast goes on but slowly. It thus follows that the floor of the middle part of the mesenteron is formed only of an extensive mass of yolk cells. This can be well seen in sections across the middle of the frog's embryo about six days after impregnation. Plate IV. fig 3, is a drawing of such a section, and the lateral continuity of the hypoblast with the ventral yolk cells is well shown. The first rudiment of the liver is found in sections of a frog's embryo of about seven days from impregnation. In its earliest stage, it consists of a ventral prolongation of the gut into the anterior part of the mass of yolk cells. The cells immediately bounding the cavity of this diverticulum are yolk cells rapidly becoming converted into hypoblast. This ventral prolongation of the gut, which we may call the primary hepatic outgrowth, passes in a direction ventralwards and forwards towards the anterior end of the yolk mass. In Plate IV. fig. 4, a section through the anterior part of the yolk region of an embryo about seven days after impregnation is depicted. The hepatic diver-

[1] Embryologists differ as to whether the blastopore becomes the anus of the adult or closes up, a new anus being subsequently formed.

ticulum is seen cut across as it is curving forwards in the midst of the yolk cells. In a section, about four or five *behind* that shown in fig. 4, the continuity of the gut with the hepatic diverticulum will be seen. Shortly after this stage, the rudiments of the heart and pericardium have made their appearance; they are found on the ventral side of the fore-gut, immediately in front of the anterior part of the yolk. The anterior part of the yolk, although perfectly continuous posteriorly with the rest of the yolk cells, soon begins to be more definitely marked off from the hypoblast above it, by the gradual closure of the lateral and ventral walls of this part of the gut. When this condition is reached, the anterior part of the yolk constitutes a forwardly directed mass, attached by a short mesentery to the gut above. This mesentery has meanwhile been produced from the splanchnic mesoblast, as the gut became more and more separated from the yolk. This anterior part of the yolk is also surrounded by a definite capsule of splanchnopleure, and is ventrally attached to the body wall below, where the somatopleure and splanchnopleure are continuous. In this constricted off portion of the yolk, the primary hepatic diverticulum lies. These points are shown in Plate IV. fig. 5, which represents a section of a frog's larva, about twelve days from impregnation, *i.e.*, about four days after hatching, and taken about fifteen sections behind the posterior limit of the heart, and just in front of the point of junction of the hepatic diverticulum and the gut. The anterior portion of the yolk above described is important, because it becomes bodily converted into the liver in the course of subsequent development, *the yolk cells being directly transformed into liver tissue.*

The steps in this conversion of yolk into liver substance can readily be traced. The first step is seen on a series of sections of a frog's larva about thirteen days after impregnation. By this time the heart, which lies immediately in front of the anterior limit of the yolk, is a fairly well-developed structure, and has already become twisted on itself, and distinguished into a dorsal or venous, and a ventral or arterial portion. By examining every section in order, behind the level of the heart, we are able to trace the venous blood-vessels from their

entrance into the sinus venosus backwards to their origin. The venous end of the heart is found to become continuous with a large vein lying in the splanchnopleure between the gut and the anterior part of the yolk. It can be traced through about ten sections, and then becomes resolved into a number of blood lacunæ lying in the midst of the localised anterior part of the yolk above referred to. These lacunæ *have no definite walls*, although a marked epithelium of flattened cells can be seen in the cavities of the heart, and can be traced along the venous trunk for some distance. The lacunæ just described are shown in Plate IV. fig. 6, which is a drawing of a section about the eighteenth behind the middle of the cardiac region. Continuing the examination, in order of the sections backwards, we find that the lacunæ are gradually lost, none whatever being found behind the junction of the primary hepatic outgrowth with the gut. In the post-hepatic region the mesenteron is still incomplete, and is quite a narrow tube, whose dorsal wall only is formed of true hypoblast. As yet there is no constriction of the anterior part of the yolk from the post-hepatic portion.

The results of the continued excavation of the hepatic part of the yolk by blood lacunæ can be studied in sections of a frog's tadpole, about six or seven days after hatching. A section taken in front of the primary hepatic diverticulum of a larva of this age, will show that the breaking up of the anterior part of the yolk by blood spaces is now so marked that a network of anastomosing cylinders of cells is found interlacing with a network of blood spaces, and taking the place of the orginally solid mass of yolk cells. This deeply excavated condition of the hepatic part of the yolk is found only in front of the primary liver outgrowth. The strands of the network of what may now be called liver substance are at this stage solid, and several layers of cells deep. I cannot, at this stage, find any trace of a wall to the blood spaces, which are therefore lacunæ, lying in the midst of a general parenchyma. These appearances are shown in figs. 7 and 8. Fig. 7 is a drawing of a section under a low power, taken about eight sections behind the posterior limit of the heart. Fig. 8 represents a portion of the liver from the same section, seen under a high power.

The further progress of the development of the proper liver

substance from these transformed yolk cells can easily be traced in sections of tadpoles of different ages. Soon a condition is reached which can with certainty be identified as practically adult liver. When the transformation of yolk cells into liver tissue has once begun, the tissue of the young organ begins to grow by cell division, which takes place chiefly in its peripheral parts, and also by extension of the cell cylinders. The organ thus grows so as to attain considerable magnitude. By the deeper and deeper excavation of the substance of the organ by blood channels, and by the gradual tunnelling of the cell cylinders so as to convert them into an anastomosing network

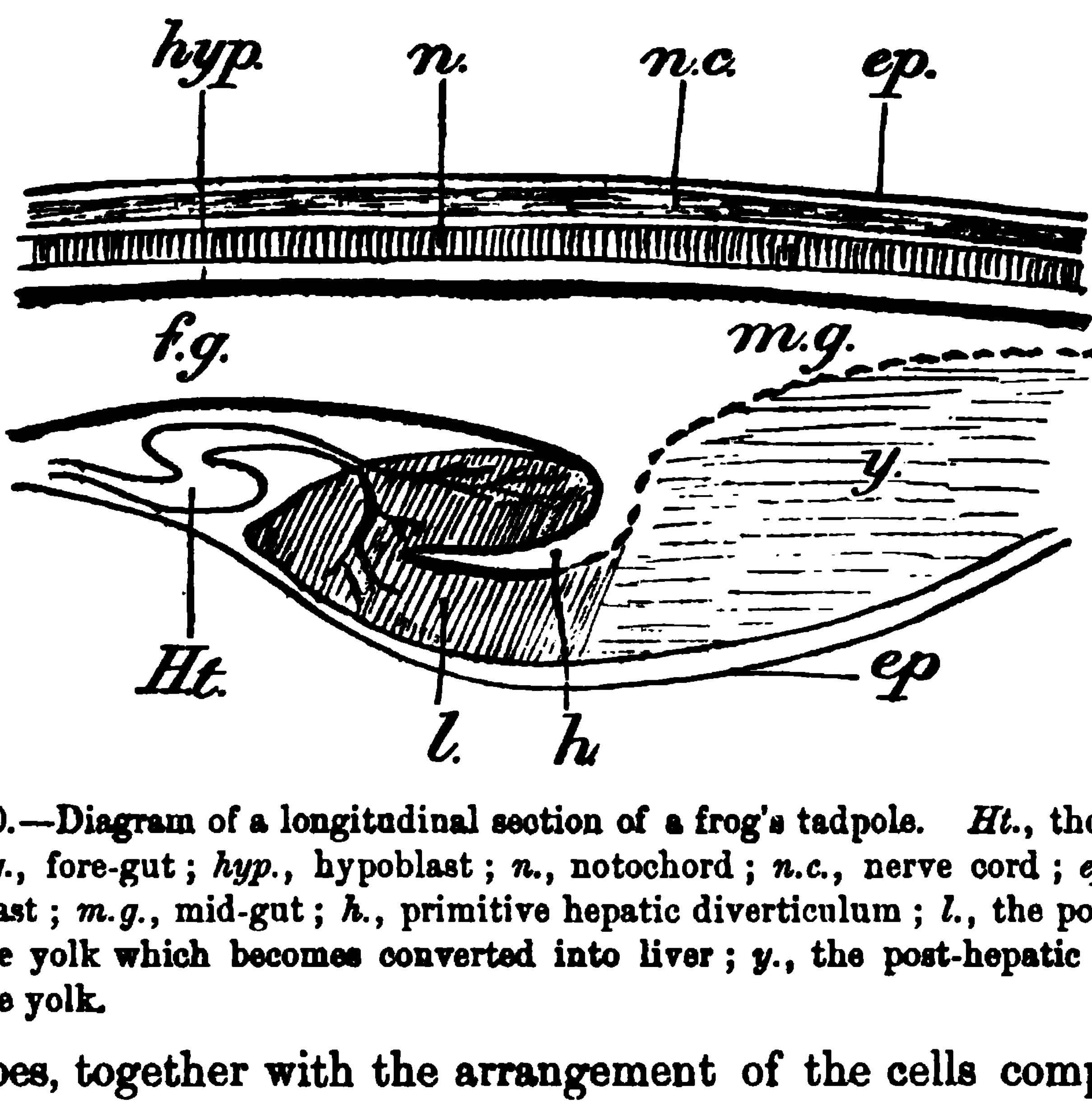

FIG. 10.—Diagram of a longitudinal section of a frog's tadpole. *Ht.*, the heart; *f.g.*, fore-gut; *hyp.*, hypoblast; *n.*, notochord; *n.c.*, nerve cord; *ep.*, epiblast; *m.g.*, mid-gut; *h.*, primitive hepatic diverticulum; *l.*, the portion of the yolk which becomes converted into liver; *y.*, the post-hepatic part of the yolk.

of tubes, together with the arrangement of the cells composing the cylinders, into a single layer around a central lumen, the characteristic features of the adult organ are acquired. A stage in this process is shown in Plate IV. fig. 9. At an early stage in the formation of the liver tubes, *i.e.*, when the cell cylinders are first penetrated by "secretion" channels, the lumina of the tubes are much more distinct than they are in the adult liver. Fig. 10 is a diagram of a longitudinal section of a frog embryo, showing the relations of the heart, alimentary canal, primary hepatic diverticulum, and yolk substance.

2. *Development of the Liver in the Chick.*—The first rudiment of the liver of the Chick is found in sections of a chick's embryo of about 55–60 hours' incubation. It consists of a cæcal diverticulum of the hypoblast growing forwards, mainly dorsal to the common vitelline vein close to its junction with the venous end of the heart. At its origin, the diverticulum lies between the two vitelline veins just prior to their junction into the common vessel (afterwards *ductus venosus*) which joins the heart. As is well known, the point of divergence of the vitelline veins at this stage marks the posterior limit of the closure off of the anterior *cul de sac* of the gut from the hypoblastic covering of the yolk sack; and the primary hepatic diverticulum really arises at this posterior limit of the fore-gut, and in such a situation that it is impossible to say whether it is a diverticulum of the gut or of the yolk sack itself. As seen in a transverse section of an embryo of this age (55 hours), the primary hepatic diverticulum is found to be compressed dorso-ventrally, and spread out somewhat laterally. A second diverticulum, arising from the hypoblast at the same point as the other, is present at this stage. This second outgrowth lies to the ventral side of the common vitelline vein, and is not so marked a structure as the dorsal diverticulum; nor does it extend so far forwards. Both diverticula are contained in the loose splanchnic mesoblast which lies just behind the heart, and are separated from the blood in the vitelline vein only by the thin epithelial lining of the latter. The two diverticula are clearly branches of one common outgrowth, the common portion lying in the angle between the two vitelline veins at their junction into a common trunk (Plate IV. fig. 11). Shortly after the formation of the primary hepatic outgrowth, the hypoblastic cells of it begin to proliferate, growing chiefly from the sides of the dorso-ventrally compressed portion. The proliferation of the hypoblast cells takes the form of solid outgrowths lying in the midst of loose splanchnopleure cells, and tending to grow around the common vitelline vein. At the same time, there take place inruptions, as it were, of capillary blood-vessels from the vitelline vein into the solid mass of proliferated hypoblast, breaking it up into more or less branched rods of

cells. Very soon the distinction between the dorsal and ventral parts of the original diverticulum is lost, and the cells produced by proliferation of the hypoblast of the two portions of the diverticulum become continuous with each other around the vitelline vein. These points can be well seen in sections of chick embryos of about 70 hours' incubation (Plate IV. fig. 12).

The production of blood capillaries in the midst of the hepatic hypoblast rapidly extends, and is so marked a feature that it is difficult to say whether the solid hepatic mass becomes broken up by the formation of blood-vessels in it, or whether cylindrical outgrowths of cells from the original diverticulum are taking place, and are splitting up the vitelline vein itself. From the descriptions ordinarily given in the works on embryology, the latter would appear to be the nature of the process. In my sections, however, I can find no definite evidence that this is so. It seems to me that the process of proliferation of hypoblast cells at the sides and extremity of the hepatic outgrowth, and the production of capillary blood-vessels by differentiation of mesoblast cells, are occurring at one and the same time, the real nature of the process being a breaking up or honey-combing of a solid mass of cells in a manner similar to the tunnelling of the yolk cells in the frog. At any rate, there is soon formed a network of solid cylinders of cells with large blood capillaries or sinuses, occupying the meshes of the network.

Very soon, *e.g.*, in an embryo of 75 hours' incubation, the line of closure off of the fore-gut from the yolk sack has extended further back, and the primary hepatic outgrowth is now found to undoubtedly arise from the gut, and not from the indifferent region between closed gut and yolk sack, as was the case at the earlier stage already described.

The process of production of hepatic cylinders goes on fairly quickly, and by about 85 hours' incubation, the solid cell cylinders forming a network around the vitelline vein can be well seen. The blood in the vitelline vein and its capillary offshoots is only separated at this stage from the cells of the hepatic cylinders by a single layer of flattened epithelium, the walls of the vein and its capillaries being alike in this

respect. The cell cylinders are at this stage composed, in some places of two, but mostly of three or four layers of cells. By about 90 hours' incubation, the production of cell cylinders has much advanced, and the general appearance of the organ under a low power is, at first sight, very like that found in the adult state of the liver of a fish. Under a high power, moreover, the cells of the hepatic cylinders, in some parts, have begun to be arranged in a single layer around a lumen. In other parts, notably the peripheral portions of a section, the proliferation of the hepatic hypoblast is still taking place, and the cell cylinders here are still solid, and, in some places, form masses of cells several deep, and as yet not excavated by blood capillaries. The appearances found in a section at this stage, therefore support the view above expressed that a solid mass of hypoblast is really split up by the formation of blood channels in it (Plate IV. fig. 13).

As to whether the cell cylinders are originally solid or hollow there is a difference of opinion amongst observers. Balfour found that they are hollow at first in Elasmobranch fishes, in Amphibia, and in some Mammals. Remak and Kölliker both described them as originally solid in Aves. Kölliker also found them to be solid in the Rabbit. I am quite satisfied from my specimens that they are originally solid in the Chick, and also in the Frog. The extent to which the primitive hepatic diverticulum itself contributes to the formation of liver substance is clearly small. Although it branches somewhat, yet it penetrates but slightly into the developing organ, whose proper tissue evidently results from a proliferation at the extremity of the diverticulum. The proper liver substance is obviously not produced by any extensive branching of the original diverticulum as a tube, whose walls might form hepatic cells. It is quite easy to distinguish the primary hepatic diverticulum and the hepatic cylinders from each other in a section of, say, a 96 hours' Chick, for not only are the lumina of the diverticulum and its branches very large, as compared with those in the developing proper tissue, but the characters of the cells forming the walls of the two structures are different.

The facts in the development of the liver of the Chick here

summarised completely establish the opinion which Lewis Jones and I arrived at in our paper on the vertebrate's liver, already alluded to. We suggested there that the primitive hepatic diverticula alone have developed into bile ducts, and that the solid cell mass produced at its extremity, and from which the proper liver tissue is developed, is to a great extent distinct from it. It is clear also that the minute biliary channels in the hepatic cylinders are not produced by an extension of the lumen of the primitive diverticula, but by the secondary formation of more minute channels in the midst of solid rods of cells. The same facts are found in the young liver of the frog's tadpole—the extent to which branches of the primitive diverticula have extended into the organ to form fine ducts is but very limited.

The minute characters of the liver, whose early development in the Chick is thus briefly described, undergo but little change in the later stages of incubation. The texture of the organ, however, becomes more dense, and the network of hepatic tubules less easy to recognise. The network, however, always remains recognisable in well-stained specimens even to adult life. A figure of the appearances presented in a section of the liver of a Chick just hatched is given in the *Journal of Physiology*, vol. x., plate xxviii., to which the reader is referred. One fact as to the appearance of the liver in the later stages of incubation must, however, be particularly noticed. It gradually acquires the same general colour and appearance as the yolk of the egg, and except that it is more dense might by a careless observer be mistaken for it on naked-eye examination. I have not yet had time to examine into the nature of the pigment which gives the liver of the later portions of incubation this appearance, but I have little doubt that the pigment is the same which is present in the yolk, and that it has been transferred to the liver from the yolk in the course of development. The liver cells in a just hatched Chick, moreover, are deeply excavated by spaces for oil drops. These facts must clearly have some importance in connection with the question of the functions of the liver during embryonic life.

3. *Development of the Liver in Mammals.*—As to this part of the subject I have at present only a few scattered observations on the livers of rabbit's, pig's, and cat's embryos.

In a cat's embryo about 5 mm. in length, I found that the production of a network of liver cylinders has already taken place. These cylinders are, however, solid, not having yet become tunnelled by the production of biliary channels. The cells of the cylinders, moreover, as yet show no sign of an arrangement into a single layer; the cylinders are, in fact, several layers of cells in thickness, and show no signs of having been formed by anastomosis of primitively distinct rods. The whole appearance is suggestive of an originally solid mass having been broken up by the production of blood spaces in it. The blood spaces have a wall of a single layer of epithelium, which can be traced by the elongated, oval, deeply-stained nuclei, at the margins of the blood spaces, and between them and the masses of liver cells. A good idea of these appearances may be obtained by inspection of Plate IV., fig. 14.

In a section through the liver of a cat's embryo 15 mm. in length, the production of proper hepatic tissue has considerably progressed from that above described. It now has a striking resemblance to the liver of an adult fish, *e.g.*, the eel. It is composed of a network of anastomosing tubules measuring about 30μ across. Where a strand of the network has been cut transversely, the tubule is found to consist of a single layer of cells, arranged around a small central lumen, about five cells being required to complete the circle of the section. The nuclei are distinct, and lie in about the centres of the cells. The whole arrangement is very irregular, and the blood spaces occupying the meshes of the network are large (Plate IV., fig. 15). The walls of the blood spaces are well formed, and there is as yet no trace of a lobule.

Although the two embryos whose livers are here briefly described are, so far, isolated specimens, yet, taken together, they indicate that the liver of the Cat is developed in much the same way as that of the Frog and Chick, viz., by the production of a network of solid rods from a primitively continuous mass by the development of blood-vessels in it, and the subsequent secondary formation of biliary lumina in the solid cylinders.

D. *Theoretical Considerations.*

The account of the development of the liver in Vertebrata

given in the foregoing pages, is, I think, sufficient to justify the following conclusions:—

1. The liver, at the time of its primary origin, and also throughout development, is intimately connected with the yolk or with the yolk sack. In some cases, *e.g.*, the Frog, yolk cells are actually converted into liver substance.

2. It has a very intimate association with the blood-vessels which carry blood from the yolk sack, or its equivalent, to the heart.

3. The liver begins to be developed at a time when the absorption of the yolk and its utilisation for the supply of food to the growing embryonic cells is beginning to be particularly active.

4. The liver is primitively a simple saccular outgrowth from the alimentary canal, and is preserved in this state in the adult of one Chordate only, viz., the *Amphioxus*. This clearly represents the first step in its evolution.

5. The cæcal pouch thus evolved does not become drawn out into saccular prolongations as in invertebrates, but gives rise to a solid mass of cells at its extremity.

6. The solid mass of cells produced in this way becomes the proper liver tissue of all those Chordates which possess anything more than a simple outgrowth (all those higher than *Amphioxus*).

7. All the types, in which a solid mass of liver cells is produced, have also a certain amount of yolk substance.

8. The originally solid mass of hepatic cells early becomes broken up by the production in it of blood capillaries connected with, or in the course of, the veins of the yolk sack.

9. The minute "biliary" canals of the liver substance are formed subsequently by the hepatic cells arranging themselves around central lumina.

10. These "biliary" channels are not formed by the extension of the original diverticulum of the gut, but separately, and subsequently open into the original outgrowth, as it were, into a common duct.

These conclusions seem to me to clearly indicate that the proper liver tissue is first evolved as an embryonic organ of nutrition, and for the purpose of producing some change in yolk

substance to fit it for use as an immediate formative material in the metabolism and growth of embryonic cells and tissues. I should imagine that the crude food yolk—a more or less solid material—becomes liquified by the action of the hypoblastic cells of the yolk sack (or by a ferment produced by them), and is then absorbed and carried by the veins of the yolk sack towards the heart. In its course, this absorbed yolk substance is carried in the blood of the yolk veins through the capillary vessels of the young liver, whose cells, I imagine, further act upon it, and elaborate it into some substance more immediately fitted to be utilised for the construction of new protoplasm by the general embryonic cells. It is, I think, generally held by physiologists that the liver of the adult performs some such functions, elaborating or otherwise acting upon the absorbed products of digestion brought to it by the "portal" system. It is certain that it acts in this way in constructing glycogen from the sugars of digestion, and it is probable that it behaves similarly upon the proteids of digestion (whether they are brought to it as peptones, or, as is more probably the case, in the form of an albumin, into which peptone is converted during absorption). For purposes of comparison of the embryonic alimentary system with that of the adult, we may liken the hypoblastic surface, covering and adjacent to the yolk, to the endodermal digestive surface of the adult alimentary canal. From it, "digested" food is absorbed into the blood of the yolk veins as it is into the radicles of the adult "portal" system. The veins of the yolk sack behave with respect to the liver just as the "portal vein" in the adult does. In fact, the vitelline veins of the embryo might quite appropriately be called the "embryonic portal system." I see no reason to doubt that the embryonic liver acts on the crude food material in the blood of the yolk veins just as the liver does on that of the "portal" blood of the adult—in fact, the latter would seem to be but a continuation into adult life of functions performed by the same organ in the embryo. These considerations are not only consistent with all that is known of the development of the liver, but also serve as a highly probable explanation of some otherwise inexplicable facts as to its origin and structure, and of the curious relations to the blood system which this organ has in the embryo.

Probably, at first, all the hypoblastic cells, not only those which will form the walls of the gut, but also those immediately covering the yolk contained in the yolk sack, have the power of producing all the changes in the food yolk which are necessary to fit it for use by the developing cells of the embryo. Later on, as the embryo increases, and its cells begin to become more specialised, probably the function of rendering the yolk suitable for use becomes divided into two parts, on the principle of physiological division of labour. One portion of this function, viz., "digestion," and absorption of yolk into the blood capillaries of the *area vasculosa*, continues to be performed by the general hypoblastic surface, whilst the further elaboration of the absorbed yolk substance becomes relegated to a specialised part of the hypoblastic surface, which grows out as a diverticulum from the rest (the primitive hepatic outgrowth). Then, to bring the blood of the yolk veins into closer relations with these specialised hypoblastic cells, a proliferation of the cells at the end of this diverticulum takes place, and it at the same time becomes penetrated by blood capillaries. Thus the process of "digestion" of the food yolk becomes split up into two steps, comparable to the "exterior digestion," and the "interior" or "interstitial digestion" of Claude Bernard.[1] In this summary we have an explanation of—(1) The curious relations of the liver to the blood-vessels of the yolk sack; (2) the peculiar nature of the liver tissue itself, viz., *a network of, at first, solid cell cylinders without membranous coverings or basement membranes interlacing with a network of blood capillaries*; (3) the very large development of the liver in the embryo, when such an organ can have no "glandular" functions of any importance; (4) the fact that in some animals the proper liver tissue is actually developed by transformation of yolk cells; (5) the fact that, in later stages of incubation in the Chick, the liver becomes impregnated with yolk pigment.

Not only does the liver act as the elaborator of the crude yolk in the embryo, but it probably also, particularly in the later stages of embryonic life, becomes a storehouse of reserve substance, which is being absorbed faster than it is needed by the developing tissues, and so fat, glycogen, and possibly reserve

[1] *Leçons sur les phénomènes de la vie*, t. ii., 1879.

proteid substance, becomes stored in it for future use. A continuation of this function into adult life is seen in the "glycogenic" function of the fully-formed organ, and it is not improbable that the liver of the adult is a storehouse of reserve proteid substance also.

We have now to explain how the solid hepatic network comes subsequently to be a network of tubules with fine lumina draining into the hepatic duct or primary diverticulum. A little reflection will make it clear that, if the liver cells are in the embryo actively metabolic, producing an elaborated food substance, there would probably be formed also some waste materials, which not only are of no further use, but which must be got rid of or excreted. This end could quite easily be attained by the liver cells arranging themselves in rows around central drainage channels, penetrating the axes of the cell cylinders. Into the minute drainage channels thus constituted the waste or degradation products of the hepatic metabolic processes could easily be discharged, and, making their way to the primitive diverticulum, could, for the time, be got rid of. I believe this to be the original nature of the "biliary" secretion channels; and that some such process is occurring in fœtal life is evidenced by the well-known "meconium" of the fœtus. The production of this substance is merely an accidental accompaniment of the performance of the proper hepatic functions of the embryo. The same production and excretion of waste useless material is continued into adult life in the formation of bile. Of all the fluids poured into the alimentary canal, in the adult, the bile is the only one which contains no digestive ferment, and has no digestive properties, beyond the purely mechanical one of assisting in the emulsification of fat.

It will be seen from the foregoing that I am distinctly of opinion that the liver is, primarily and essentially, an organ of nutrition, and that bile formation is only quite a secondary and subsidiary function of it. Perhaps, however, it is a question whether the earliest step of all in the origin of the vertebrate's liver, viz., the stage which remains permanently in *Amphioxus*, does not represent an organ of "secretion" rather than an organ of nutrition. Other than the saccular "liver," the *Amphioxus* has no "gland" in relation to its alimentary canal, and it may,

in this animal, be of secretory function, producing a poly-enzymatic fluid, and so be comparable to the simple saccular "livers" of invertebrates. Whether this be its primary nature or not in *Amphioxus*, we must not lose sight of the fact that this animal has now been shown to possess a "portal" system of veins quite comparable to that of higher vertebrates, and also of the fact that in no invertebrate has anything like a "portal" system of blood-vessels been shown to exist.

We have already been led to conclude that the vertebrate's and invertebrate's "liver" differ fundamentally in structure, and that the former was not evolved from the latter. The account of the development of the liver in the frog, chick, and mammal accentuates this conclusion; and in answer to the inquiry—How, then, was the vertebrate's liver evolved?—the facts above described and discussed seem to point to the conclusion, *that this organ primarily arose as an embryonic "organ of nutrition," evolved* pari passu *with the evolution of those vertebrates which produced large yolked ova.* We also conclude that after it has been evolved in this way, the organ persists into adult life by being adapted to perform the same functions in the adult as it does in the embryo.

Lately, the view of Gaskell,[1] that the ventricles of the brain and the spinal canal of vertebrates represent the stomach and intestine of a crustacean-like ancestor, around which the supraœsophageal and infraœsophageal ganglia, and ventral nerve chain of such an ancestor have grown, has received very considerable support from the facts recently published by him in a second paper[2] on this subject. If Gaskell's theory be correct, that a crustacean alimentary canal has become invaded by and enclosed within the central nervous system in the vertebrate, it is clear that the crustacean "liver" could not be the morphological equivalent of that of vertebrates. Some of the conclusions, therefore, at which I arrive in this paper are quite in harmony with Gaskell's theory, and form, so far as they go, a point in confirmation of his views. Gaskell, moreover, has

[1] "On the Relation between the Structure, Function, Distribution, and Origin of the Cranial Nerves, &c.," *Journal of Physiology*, vol. x. p. 153, 1889.

[2] "On the Origin of Vertebrates from a Crustacean-like Ancestor," *Quart. Jour. Mic. Sci.*, Aug. 1890.

found remnants of what he identifies as the crustacean "liver," lying outside the brain substance, within the cranial cavity of the Ammocœtes. I regard this as a fact of very great importance, and one which, if justified, is confirmatory of the conclusion which I have independently arrived at, that the liver of vertebrates has not been evolved from the "gland of the mid-gut" of any invertebrate. I am, however, not quite satisfied, from a perusal of Gaskell's description and an inspection of his drawings of the cellular mass which he identifies as the crustacean "liver," that it has the appearances which one would expect to find in the degenerated representative of the normal crustacean "liver" which I have described in this paper; nor am I satisfied that the appearances which Gaskell has found in Ammocœtes are those which, from my examination of invertebrate "livers," I should have expected this organ in the archi-crustacean to possess. The peculiar tissue which Gaskell describes and figures in Ammocœtes, appears to consist of a closely packed mass of large cells, each having a nucleus surrounded by remains of a protoplasmic body. Between the cells there appear to be deeply pigmented lines, but, Gaskell says, no connective-tissue elements. Gaskell finds that "these cells are solid polygonal bodies, pressed together in all directions without any sign of being in connection with specially arranged connective-tissue elements either in one direction or the other . . . . . the staining material in the cell consists of a broken-down network which starts from the nucleus and forms scanty strands which pass towards the periphery." As to the nature of the pigmented lines between the cells of this peculiar tissue, Gaskell says—"These lines and collections of pigment are the remains of the blood channels which supplied the cells of the old cephalic liver with blood." This description of Gaskell's would lead one to infer that the degenerate tissue which he describes, if liver at all, was built up on the plan which I have shown is that of the proper tissue of the vertebrate's liver, viz., a solid mass of cells penetrated with blood-vessels and with no connective-tissue elements. If it were known that the crustacean or archi-crustacean "liver" had the same plan of structure as the vertebrate liver, then Gaskell's conclusion that this tissue "is precisely what one would expect if it represented the degenerated remains of the

cephalic liver of the crustacean-like ancestor of the Ammocœtes" would, I think, be fully justified. But, on the contrary, the fundamental type of structure which I find in the "gland of the mid-gut" of crustaceans, in its simplest form, is that of a duct with loose saccular cæcal dilatations lined by epithelial cells planted on a wall of connective tissue. If Gaskell's peculiar tissue were really the remains of crustacean "liver" I should have expected to find some evidence of the collection of the cells into groups surrounded by some connective tissue to represent the cæcal pouches, the cavities of which might or might not have already been obliterated. For this reason, although I am not prepared to deny Gaskell's interpretation of the peculiar tissue of Ammocœtes, I find it difficult to unreservedly accept it.

E. *Summary.*

1. The "liver" of invertebrates is *not* morphologically the same as that of vertebrates.

2. The "liver" of invertebrates is the gland of the mid-gut, and has, when present, fundamentally the same nature in all.

3. It is composed in invertebrates of cæcal pouches, lined by secreting epithelium, surrounded by connective-tissue membranes.

4. In the Vertebrata, the liver is made up of a network of tubules, interlacing with a network of blood capillaries, and unprovided with any basement membrane separating the blood capillaries from the liver cells.

5. The invertebrate's "liver" is essentially a gland, secreting a digestive fluid containing ferments.

6. The vertebrate's liver is primarily an organ of nutrition for the embryo; and has been adapted to perform similar functions in the adult.

7. In its evolution, the vertebrate's liver is intimately associated with the absorption of the food yolk of the egg.

8. The vertebrate's liver has *not* been evolved from the "gland of the mid-gut" of any invertebrate.

9. The pancreas of the vertebrate is somewhat similar in structure and functions to the "gland of the mid-gut of invertebrates; although the question of whether these two organs are morphologically equivalent is an open question.

EXPLANATION OF PLATE IV.

Fig. 1. "Hepatic" cæca from a section of the "liver" of *Mya arenaria*. *a.*, connective tissue wall of the cæca; *b.*, deeply stained portion of the "hepatic" cells, containing nuclei; *c.*, honey-combed part of the protoplasm of the "liver" cells; *d.*, cavity of cæcum.

Fig. 2. "Hepatic" cæca from a section of the "liver" of *Astacus fluviatilis*. *a.*, connective tissue basement membrane; *b.*, "liver" cells; *c.*, cavity of the cæcum; *d.*, deeply stained inner border.

Fig. 3. Transverse section of a frog's embryo about six days after impregnation. *ep.*, epiblast; *n.c.*, nerve cord; *n.*, notochord; *hyp.*, hypoblast; *p.*, mesoblastic somite; *mes.*, mesenteron; *so.*, somatopleure; *spl.*, splanchnopleure; *y.*, yolk cells.

Fig. 4. Transverse section through the anterior part of the yolk of a frog's embryo about seven days after impregnation. *n.c.*, nerve cord; *n.*, notochord; *hyp.*, hypoblast; *mes.*, mesenteron; *y.*, yolk cells; *h.*, primary hepatic diverticulum.

Fig. 5. Transverse section of a frog's larva about twelve days after impregnation. *W.B.*, Wolffian body. Other references as in figs. 3 and 4.

Fig. 6. Transverse section through the anterior part of the yolk region of a frog's larva about thirteen days after impregnation. *b.lac.*, blood spaces in the midst of yolk cells. Other references as in preceding figures.

Fig. 7. Transverse section through the same region of a frog's larva about fifteen days after impregnation. *l.*, liver. Other references as before.

Fig. 8. A portion of the same section as seen with a high power. *b.lac.*, blood spaces in the liver; *hep*, network of liver cells.

Fig. 9. Section of the liver of a frog's tadpole about five days older than that from which figure 8 is drawn. *mes.*, intestine; *h.*, primary hepatic diverticulum, *i.e.* hepatic duct; *hep.*, network of liver tubules, each composed of a single layer of cells around a central lumen; *b.lac*, blood spaces.

Fig. 10. See page 183 of text.

Fig. 11. Transverse section of a Chick embryo of about 60 hours' incubation. *n.c.*, nerve cord; *n.*, notochord; *ao.*, aorta; *p.c.v.*, posterior cardinal vein; *so.*, somatopleure; *spl.*, splanchnopleure; *am.*, amnion; *v.v.*, common vitelline vein; *h.*, primary hepatic diverticulum; *h'.*, ventral branch of the primary hepatic diverticulum.

Fig. 12. Transverse section across the region of the developing liver of a 70 hours' Chick. *p.c.v.*, posterior cardinal vein; *ao.*, aorta; *p.p.*, pleuro-peritoneal cavity; *i.*, intestine; *h.*, primary hepatic diverticulum; *so.*, somatopleure; *spl.*, splanchnopleure; *v.v.*, vitelline vein; *am.*, amnion; *l.*, network of liver cylinders; *c.*, capillary blood-vessels of the liver.

Fig. 13. Portion of a longitudinal section of a 96 hours' Chick

embryo. *e.*, epithelial lining of the blood capillaries of the liver; *c.*, the blood spaces. Other references as in figs 11 and 12.

Fig. 14. A portion of the liver of a cat embryo about 5 mm. in length. *a.*, solid cylinders of liver cells; *b.*, blood spaces in the solid mass dividing it into a network; *c.*, epithelial lining of the blood spaces.

Fig. 15. A similar section of the liver of a cat embryo about 15 mm. in length. *a.*, lumen of liver tubule; *b.*, liver tubule; *c.*, blood in the blood capillaries; *d.*, epithelial lining of blood capillaries.

THE MEANS BY WHICH THE OILY DÉBRIS IN CATARRHAL NEPHRITIS IS REMOVED FROM THE TUBULES. By D. J. HAMILTON, M.B., *Professor of Pathological Anatomy, University of Aberdeen.*

THE belief is almost universal that the oily matter which accumulates in the convoluted tubes in catarrhal nephritis, as a result of degeneration of the desquamated epithelium, is washed out into the collecting tubes, and is in this way removed. Oily and epithelial tube casts are found in the urine, a circumstance which seems to place this view beyond contradiction. Although I do not mean to assert that none of the oily matter is thus got rid of, yet careful study of the kidney in acute catarrhal nephritis, as well as of some instances of what is known as chronic catarrhal nephritis, has convinced me that this statement is only partially true—true, indeed, only so far as the accumulation in the secondary coil is concerned, not in regard to that in the primary coil.

It has always been difficult to account for the casts formed in the primary coil making their way past the loop of Henle. These casts are often from two to three times the width of the limbs of Henle's loop, and hence to allow of their passage either the loop must have stretched inordinately or the cast must have become compressed and attenuated.

On examining the condition of the loop of Henle lately in a number of cases, in order to make certain of its bearing in this disease, I was much surprised to find that not in a single instance was I able to discover any of the oily and granular matter within it or its limbs so abundant in the neighbouring convoluted tubules. Nor did the loop, a little swelling of its epithelium excepted, appear to be materially altered. I utterly failed to detect any evidence of stretching. In one instance of general hæmorrhage throughout the organ, a loop was seen with a little blood in it. The general conclusion therefore arrived at by this inquiry was that the loop of Henle is comparatively little involved even in severe cases of catarrhal nephritis.

For long I have been struck by the fact that in many instances of catarrhal nephritis, more particularly where at the time of death the disease has been undergoing resolution, not only are oil globules to be seen within the tubes, but also that the intertubular spaces contain large numbers of them. At first sight, their presence in the latter situation might seem to indicate a fatty degeneration of some of the intertubular tissues. What the intertubular tissues are which go to furnish them, however, does not seem quite clear, and there are other circumstances which cast disfavour upon this notion.

A preparation of late came under my notice which cleared up the whole difficulty in accounting for them, and since then I have found many confirmatory specimens. It demonstrated, in the clearest manner possible, that the oil-globules outside the tubes have originally been within them; that they have made their way through the wall of the tube; and are now in process of being absorbed by the intertubular lymphatics.

According to Rindowsky (*Centralblatt f. d. med. Wissensch.*, vii. p. 145, 1869,) the large lymph-vessels of the kidney follow the blood-vessels. The main arterial trunks are each accompanied by two large branches which envelope them in a network of anastomosing offshoots. The vas afferens of the glomerulus is also surrounded by a network of vessels which partly penetrate into the tuft. The vas efferens, after its exit, is accompanied by several comparatively large trunks which break up into a lymph capillary plexus. The small branches of the cortical arteries are also accompanied by lymphatics; and in the adventitia of the veins leaving the organ there is a rich lymphatic network. Between the convoluted tubes are numberless lymph spaces and vessels, and around the straight tubes of the medulla a similar plexus exists. Between the layers of the capsule of the organ are very large lymphatic vessels easily injected artificially. These seem to have a free communication with the lymphatic system of the cortex.

The renal lymphatics throughout their course retain the character of true vessels even up to their finest terminations, and have a distinct endothelial lining.

The oil globules referred to above, as seen between the tubes, do not follow an irregular course, but are always found to take

one direction. They pass out of the tube in rows, the tube through which they escape usually being denuded of its epithelium and distended with oil and granular matter. Thence they seem to infiltrate angular lymph spaces lying between the tubules, and invariably make their way outwards towards the capsule. Arrived at the extreme surface, they appear to accumulate here in quantity, but ultimately emerge into the cavern-like lymphatic trunks of the capsule. In one instance I found the latter completely injected with them. So far as I have seen, they never pass inwards to the medulla. The tubular interspaces in this region are quite free from oil, and, in a suitable case, contrast in a remarkable manner with the black appearance of those of the cortical substance.

The fatty epithelium in the secondary coil seems to be partly absorbed partly extruded. It is quite possible that, although the primary coil contains even a considerable quantity of degenerated epithelium, urine may still pass along it and succeed in washing out the accumulation in the secondary coil. This view is supported by an example I met with where the disease was becoming chronic. In this kidney the secondary coils were quite free from fatty casts or any accumulation whatever, but in nearly every one of the primary coils a black oily mass was visible. The mass occupied only that part of the tube adjacent to the descending limb of the loop of Henle, that is to say, the part usually known as "the spiral tube of Schachowa." It looked as if the epithelium and oily matter had been driven into this from the pressure of the urine behind. Not a particle of débris, however, could be found in any single instance in the loop of Henle. The cast contained in the spiral tube reached down as far as the commencement of the descending limb, and was often pointed, as if an effort had been made to drive it onwards—an effort which seemed to have been signally unsuccessful.

The above facts appear to show—

1. That a great part of the oily residuum in the tubes in catarrhal nephritis passes through the walls of the tubes and is removed by the lymphatics.
2. That the part of the tubular system of the kidney where this chiefly occurs is the primary coil.

3. That very little if any of the detritus resulting from the destruction of the tubular epithelium of the primary coil escapes by being washed out, the loop of Henle effectually interposing an almost complete barrier to its passage.
4. That the loop of Henle participates very little in the catarrhal changes, and, as a rule, is comparatively healthy.

DISSECTION OF A SYMELIAN MONSTER. By R. C. BENINGTON, M.B., B.S., *Newcastle-on-Tyne.* (PLATE V.)

SYMELIAN monsters are of sufficient rarity to make a specimen one of interest.

Reports of authentic cases are difficult to find.

Palfyn, in his work on "Monstrosities," mentions a child without feet, having its thighs joined, and ending in a sort of point, date 1553. But no attempt is made at an anatomical description.

The family is characterised, as the name implies, by a union more or less complete of the lower limbs, and the classification adopted by Geoffrey St Hilaire[1] is based upon the extent of union, and the existence or absence of various bones or toes.

1. Symelic, in which the two lower limbs are united, are very complete—two feet with the soles turned to the front.

2. Uromelic, in which the two lower limbs are united but are incomplete, the limb containing sometimes three bones, sometimes two, and only one patella. The foot is usually very incomplete in the number of bones—either tarsal, metatarsal, or phalanges. In this class of fœtus there is neither anus nor urinary passages. The internal sexual organs are wanting on either one or both sides; when present are usually male. The external organs are frequently present.

Two cases of this kind are reported as having been born alive. One lived nine hours and swallowed a little pap.

3. Sirens, in which the two lower limbs are united, are very incomplete, ending in a point, without a distinct foot, or the foot being represented by a toe or rudiment of a toe.

In a case described by Hofer,[2] there is behind the segment resulting from union of lower limbs a tail-like appendage, less long than the segment, soft, vascular, spongy, and without muscular fibres, obtuse at its extremity, inserted like an animal's tail, just above the anal orifice. Superville[2] also

[1] *Histoire des anomalies, ou Traité de Teratologie*, vol. ii., 1836.

[2] Quoted by St Hilaire, p. 252, vol. ii.

Fig. 3.

F Huth Lith^r Edin

describes a Siren, in which a little pig-like tail was inserted above the anus on the middle of sacrum.

The terminal segment usually consists of one bone, analogous to the tibia.

This form is more common than the others. In them, out of twelve reported cases three were females, one male; in nine, the organs were too rudimentary for differentiation, or were absent.

The intestines are badly formed in the post-cæcal region. The end of the colon and rectum are wanting. These have been born alive at full term, and have lived from six to twenty-four hours, one executing various movements, cried, and swallowed.

St Hilaire describes to some extent the anatomical peculiarities of a Symelic fœtus, and his description tallies well with those observed by myself in the following:—

The child was born at full term. Above the pelvis it was well developed and perfect.

The lower limbs were united from the pelvis downwards. There were two feet, with the soles turned anteriorly, but only nine toes, the second toe of the left foot being absent. The left big toe was almost at right angles to its normal position, and long, having much the appearance of the similar toe of an ape.

There was an entire absence of external genito-urinary organs, and no sign of an anus.

In the position indicated in fig. 1 was a pig-like caudal appendage. Above this the spinal column ended in a truncated extremity directed backwards.

On opening the thorax the conditions found were normal. The lungs were small, and occupied only the back part of the thoracic cavity. They were of a light reddish-brown colour, and sank in water. On opening the abdomen nothing abnormal was found until reaching the cæcum. Above this point the intestine was enlarged, filled with meconium, and the sigmoid flexure ended in a blunted cone. The spleen and liver were normal.

The supra-renal bodies were present and large.

The kidneys, ureters, and bladder were entirely wanting.

The testicles were in the inguinal region.

There was only one umbilical artery.

Most of these features will be seen on fig. 2, which also shows the position of the limbs. They will be seen to be turned outwards, so that the patellæ are placed externally and posteriorly.

The tibiæ and fibulæ have a greater degree of rotation than the femora. The fibulæ are both present, near to each other in the middle line. In consequence of this rotation, the muscles seen above the knee are more or less normal, consisting of the adductors, sartorius and gracilis, whilst below the knee the normally posterior muscles are anterior. They are the flexor longus hallucis, flexor longus digitorum, and tibialis posticus.

Internally, above the knee, are seen two muscular strips passing upwards and outwards between the adjacent surfaces of the femora. In the middle line is a muscle which I take to represent the gastrocnemius.

The small femoral arteries are seen to end in the patellar plexus.

There is only one posterior tibial artery which supplies the plantar aspect of both feet. In this diagram also are seen a few branches of the antero-crural nerve and two posterior tibial nerves—the larger, the right, supplying the plantar surfaces of both feet; the smaller, the left, going to the big toe of that side.

The fuller development of the right limb will also be noted.

On dissecting the back the tail was found to be surrounded by muscular fibres which emerged from the pelvis, of which further detail is given on 208.

Fig. 3 is a posterior view with the left gluteus maximus cut.

It shows above the knee the following muscles:—Tensor fasciæ, rectus and vasti, and sartorius externally. Below the knee, the four internal tendons are the peronei, then the extensor longus digitorum, extensor hallucis, and tibialis anticus.

Internally, at the level of the knee-joint and above, are seen the two femoral heads of the biceps and a median slip all continuous with the peroneus longus. The great and small sciatic nerves and a large median artery are seen to emerge from the pelvic outlet. The union of the two great sciatic nerves into

one median popliteal, and two external popliteal is also shown. In the leg are seen the anterior tibial arteries and nerves.

The following muscles were found, and were normal in their attachments:—Psoas, iliacus, tensor fasciæ, sartorius, gracilis, rectus femoris, vasti, pectineus, adductors brevis and longus, gluteus maximus and minimus, obturator externus, tibialis anticus, extensor longus digitorum, extensor hallucis, peroneus brevis, flexor longus hallucis, flexor longus digitorum, tibialis posticus, extensor brevis digitorum.

The following deviations were noted:—The adductor magnus came too far down; it appeared to become continuous with the posterior ligament of the knee-joint, and was attached to the back of the tibia, in the position of the normal semimembranosus.

The popliteus was very immature; only a few indistinct muscular fibres indicated its position.

The Gluteus Medius.—The posterior fibres of this muscle, opposite the part corresponding to the great sacro-sciatic opening, passed into the pelvis, where they intermingled with others of intra-pelvic origin, and invested the tail in both its intra- and extra-pelvic portions.

Nothing corresponding to the semimembranosus, or semitendinosus, or long head of biceps could be found. The femoral head of each biceps was normal, and the two muscles passed downwards, and at the space between the condyles of the femora and above they were separated from each other by a muscular mass, which was clearly defined from them. Below, the biceps and this median mass passed imperceptibly into the peroneus longus. They seemed to be attached to a fibrous aponeurosis from the upper part of the condyle of the femur to some distance below the head of the fibula.

Taking origin from the anterior side of this aponeurosis on both sides, and therefore being connected to the back of both condyles of the femora, was a fleshy mass two centimetres long and five wide, ending abruptly in a fine tendon, which, passing downwards, was attached to the inner and back part of the internal malleolus of right tibia; this I have taken to represent the gastrocnemius and tendo Achillis.

There was nothing to represent the soleus.

Stretching between the femora were two muscular slips

arising from the adjacent borders, and, passing downwards and inwards, to be inserted along the adjacent surfaces of the opposite femora, thus forming a crucial muscle, the one having its highest attachment to the left femur being anterior (fig. 4).

On opening a hip-joint the appearances were normal. On opening the right knee-joint it was seen that the synovial membrane passed from the femur, immediately below the patella facet to blend with the infra-patellar pad of fat, thus representing a broad ligamentum mucosum. In this way the joint between patella and femur was lined by a synovial membrane, distinct from that of the general joint cavity, except that there was a continuity between the two synovial cavities over the front of external condyle. Both semilunar cartilages were present. No transverse ligament connecting them anteriorly could be made out.

Both crucial ligaments were present.

The great trochanters were closely approximated and held together by a dense fibrous structure.

In the lower limb there are three interosseous membranes: one between the two fibulæ and one between each fibula and tibia.

The lower end of each fibula is very large, and resembles the inferior extremity of the radius. The internal malleolus is on a much lower level than the external.

Tarsal Bones.—There is one large os calcis to which both fibulæ are articulated. There is evidence that they have been two separate bones, as a groove can be detected between them.

On the right foot, the astragalus articulates with tibia, fibula, os calcis, and scaphoid.

On the left foot with tibia and scaphoid. The other tarsal bones are all present in right foot, and apparently normal, as also the metatarsal.

On the left side, there is an absence of the middle cuneiform, and a corresponding absence of second toe.

The cuboid and external cuneiform are both present, but fused.

The sacrum is nearly at a right angle with the lumbar vertebræ; the number of sacral vertebræ is normal.

The ilia are flattened out in a marked manner; this flattening is accompanied by a close approximation of the tuberosities of the ischia, so that they are united; the acetabula being thus carried backwards, their cavities look almost directly backwards. The corresponding approximation of the pubes has resulted in a complete fusion of the ischial and pubic rami. The obturator membranes thereby form, as it were, part of the floor of the pelvis, the obturator foramina looking directly downwards. The brim of the pelvis is markedly elongated from before backwards; there is no pelvic cavity, so to speak, but a space corresponding to the inferior strait is left between the sacral angle and the united ischia, measuring two centimetres transversely, and seven antero-posteriorly. The lower end of femur has made about a quarter turn, the tibia half a turn, so that their posterior surfaces have become anterior.

At the lower border of the last lumbar vertebræ, the abdominal aorta gave off one large median artery and four lateral branches.

The large median branch passed backwards and made its exit from the pelvis, accompanied by the great sciatic nerves through the inferior strait. It passed down the back of the thigh, and at the level of the knee it divided into three: one posterior and two anterior tibial arteries. The two anterior tibials preserved their normal relations to muscles and nerves. The posterior tibial passed down the anterior surface of the leg, as seen in fig. 2, and was the main source of the blood-supply to both feet. Of the lateral branches arising from the abdominal aorta, two were external and two internal iliacs. The femorals were very small and indistinct, but could be traced down to the patella, where they ended in the patellar plexus.

The internal iliacs were not traced.

The two great sciatic nerves (fig. 3) united to form a large median trunk, which passed down the leg and divided into two, one of which, the larger, supplied both feet (plantar surfaces); the other, much smaller, only the left big toe (fig. 2).

The external popliteals divided in normal situation into muscular cutaneous and anterior tibials, the distribution of which appeared normal.

The caudal appendage, which had been cut off externally for microscopical examination, was traced inwards. It was found to become invested by muscular fibres derived from the gluteus medius and intra-pelvic fibres, and to extend upwards 2·5 centimetres, in size about the thickness of a goose-quill. It ended abruptly opposite the last lumbar vertebræ, and was densely surrounded by connective tissue, nerves, and blood-vessels. It was placed in the median line—in front of the termination of the aorta and body of sacrum. On section, it showed a minute canal, which just admitted a bristle.

The history of the case was given to me as follows:—

Mother has had three children, perfect; all alive and well.

Mother's age, 38. Both she and her husband not deformed in any way, and no history of such in other branches of family.

Full time child.

Mother says, three months ago, whilst carrying the child, she was kicked in the abdomen by the husband, which laid her up for three weeks.

I am indebted to Professor Windle, of Queen's College, Birmingham, for the following account of the microscopical appearances of the specimens submitted to him:—

"The caudal appendage is composed almost entirely of muscular tissue, chiefly arranged longitudinally, but in part consisting of transversely lying bundles. It contains an artery of some size, which runs longitudinally through it, and which, from the position occupied by the appendage, was probably the termination of the middle sacral artery.

"Another longitudinally running tube of considerable size is a vein. The nature of this was at first a little doubtful, but careful examination settled the question. There is no evidence of the presence of cartilaginous nodules in the appendage, and it certainly contains no pieces of bone. I have looked through all the chief Teratological works, but can find no account of any sireniform fœtus with a similar appendage. In an account of a Dicephalus tripus dibrachius given by Becker[1] there is mention

[1] "Dissertation," Göttingen; Abst. in *Virchow u. Hirsch. Jahresbericht Jahrg.*, xvi., vol. i. p. 271.

made of a 2 cm. long 1 cm. broad, tail-like process, which overhung the funnel-shaped opening which represented the anus. This appendage consisted of connective tissue with vessels. Ecker and His[1] have discussed the question of the presence of a caudal appendage in the human embryo, and the paper of the former author is illustrated with sections of the tail end of fœtuses at various ages. There is an account of the same condition in Sutton's *Evolution and Disease*.[2] I should think the specimen in question is undoubtedly one of these caudal appendages or skin tails. The muscular fibres, which do not appear to penetrate to its most distal part, would in this case represent the muscles of the tail, curvatores caudis, &c., representatives of which are at times met with in the human subject.

"The other section appears to be undoubtedly suprarenal capsule."

EXPLANATION OF PLATE V.

Fig. 1. Profile of undissected fœtus, showing caudal appendage and absence of external genitals.

Fig. 2. Anterior view of semi-dissected fœtus, showing terminations of intestine, rotation of limbs, plantar surfaces of feet, position of muscles, and distribution of arteries and nerves.

Fig. 3. Posterior view, showing position of caudal appendage; left gluteus maximus cut; small and great sciatic nerves, with primary division of latter; one large median artery; anterior aspect of leg and dorsal surface of feet.

Fig. 4. Posterior view of skeleton, showing pelvic outlet; fusion of tuberosities of ischia and pubic rami; position of acetabula; crucial muscle; rotation of lower limb and fusion of the two ossa calcis and cuboid and external cuneiform: absence of left middle cuneiform; *Cd*, caudal appendage; *I*, dilated end of intestine; *S*, sartorius; *G*, gracilis; *R*, rectus; *B*, biceps; *P*, peroneus longus; *cr*, crucial muscle; *AT*, anterior tibial artery and nerve; *PT*, posterior tibial artery and nerve; *V*, vein.

[1] *Arch. für Anat. u. Phys.*, (Anat. abth.), 1880.

[2] Pp. 52, *et seq.*

SOME POINTS ON THE SURFACE-ANATOMY OF THE BRAIN: AN OPEN LETTER TO SIR WILLIAM TURNER. By Professor MORIZ BENEDIKT, of Vienna.

WHEN I had the honour to develop, in the Anatomical Section of the Tenth International Medical Congress, the results of my studies upon this matter, which are in some important points opposed to the generally adopted views, I saw that many anatomists were not acquainted with my doctrines.

I know well the reason of this circumstance. I have not published my studies in the accustomed normal way in renowned anatomical journals and archives, but I have dispersed them in different journals, not as a rule read by the anatomists, and principally in my book *Anatomical Studies upon Brains of Criminals*,[1] which excited the prejudices of the profession.

But are the brains of criminals not human brains, and are the facts seen by their study not in reality facts of human anatomy? These brains present conditions from which we learn much comparative anatomy, as indeed so do also the brains of idiots, of the insane, and epileptics.

In my study of the fissures and circonvolutions of primates and other gyrencephalic animals, I have examined not only the external shape, but I have also made a great number of sections of brains of all classes, and inspected the relations to the central ganglia, the nature of the microscopical elements in the neighbourhood of fissures, and the results of vivisectional experiments and pathological facts, with the view of estimating the true value of fissures, circonvolutions, and lobes.

I tried to avoid the error so frequently committed of adopting anatomical conclusions where they are in opposition to physio-

[1] German edition, Wien, Braumüller, 1879; English edition, New York, Wood & Co., 1881, translated by Mr Fowler. See further the following papers:—(1) "Drei Chinesen-Gehirns," *Wiener medic. Jahrbucher*, 1887; (2) "Beitraege zur Anatomie der Gehirnoberfläche," *ibid.*, 1888; (3) "Der Hinterhauptslappen der Säugethiere," *Centralblatt f. med. Wissenschiften*, 1877, No. 10; (4) "Zur Lehre von der Localisation der Gehirnfunctionen," *Wiener Klinik*, 1883; (5) "Demonstration eines Verbrecher-Gehirnes," *Mittheilungen des Wiener med. Doctoren Kollegiums*, Bd. ix., 1883.

logical and pathological facts. The first great impression of the study of sections, in which the central ganglia, and their relation to the cortex, were the principal guides, was this, that the assumed great difference in the construction of brain, and in the distribution of its parts, has no existence in reality, but is only produced by the different delineations of fissures which exist in different classes of animals. This general impression was proved by the help of physiological experiment and pathological observation.

The fissures open a vast field to the *jeu d' esprit*, but are very deceptive. One or other fissure may disappear completely or partly in one class, and we consider another in the neighbourhood as its representative. We see, in other cases, that only one part of a fissure remains, and that this same part, entering into combination with another fissure, becomes difficult of identification, &c., &c. A general principle of nature is also the following: that when in a certain part of the brain the one or the other fissure is well developed, the others are reduced, or may even disappear.

I am very glad to have this opportunity of bringing the results of my investigations before British anatomists, as I am satisfied that we are more or less in harmony with each other. I shall avoid detail, and feel happy, indeed, should I carry conviction in regard to the most important points.

I. The first question to be discussed is this:—Are we justified in saying that quadrupeds have a far less developed occipital lobe than the primates?

The first argument for this view is, that the quadrupedal classes of animals have no occipital fissure. This statement seems to me to be contrary to the real condition. The stem of the fork-shaped occipital fissure[1] of man is characterised as an arc with its convexity directed towards the posterior pole, and it surrounds that part of the gyrus fornicatus which limits the splenium corporis callosi. When we search after this fissure in a great number of gyrencephalic animals, we find it, but only in connection with the fissura calloso-marginalis.

[1] Prof. Benedikt here refers to the combined calcarine and internal perpendicular fissures.

It may be remarked that in certain anomalous human brains the fissura calloso-marginalis does not come to an end, as in typical cases, by being curved upwards, so as to form the posterior limit of the paracentral gyrus of Betz. It is continued towards the posterior part, forms a limit between the præcuneal gyrus and the corresponding part of the gyrus fornicatus, and unites with the stem of the fork-shaped fissure in such a manner that this stem becomes the most posterior part of the calloso-marginal fissure.

We find the same type of the fissura calloso-marginalis in the horse. When we give, independently of the other parts, the name of the retrosplenial fissure to the stem of the occipital fissure, we shall recognise in many species of non-primate classes this fissure, which, in these cases, is often only united with the calloso-marginal fissure.

From the moment when anatomists will recognise the retrosplenial part of the calloso-marginal fissure as corresponding to the stem of the occipital fissure, they will find the occipital lobe of the non-primate classes far more animated than they had hitherto believed. I will not insist upon other details.

A direct proof that the occipital lobe of the named classes is not less developed than in primates, can be advanced from the vivisectional experiments upon apes and other mammals, and also from the pathological facts. A physiological characteristic of this lobe is that it contains the elements of visual perception. The non-primate animals see, and that without doubt, with that part of the brain which lies at the posterior pole; and, so far as we know by experience, the field of this visual element is relatively not essentially inferior to that of primates.

If we look without prejudice upon the outer surface of the posterior pole of the brain, we recognise that there exist upon a species three primitive fissures well expressed; the second has an arch, with its convexity against the occipital pole, and this arch corresponds to the fissura parieto-occipitalis externa of man. The occipital lobe is marked by a singular central ganglion, which still needs a special study.

II. It appears to me that the frontal lobe of non-primate

animals is not less diminished by anatomists than the occipital lobe, and this, too, in opposition to obvious facts.

It was a phrenological prejudice of the great anatomist Broca that he considered the so-called præsylvian fissure as the representative of the central fissura Rolandi. The characteristic quality of a central fissure in primates is, that it lies with its superior part in the centre, and with its inferior part on the posterior limit of the so-called psychomotor centres; in anatomical language it lies with its superior part in the centre of the giant cells of Betz, and with its inferior part on their posterior limit.

When we study, as I did, on sections, the position of the præsylvian fissure with reference to those cells, we find that the field of cells lies completely behind and above this fissure. Also, the most superficial inspection of a delineation of the brain of a dog or a cat, upon which is marked the position of the so-called psychomotor centres, teaches us with the same evidence that the præsylvian fissure lies in front of and below that field. Therefore it is proved that the præsylvian fissure cannot represent the central fissure; and it is not a consoling spectacle when anatomists, seduced by the error of an eminent man, have so little respect for the results obtained by physiologists and histologists.

When, on the other hand, we inquire as to whether or not there is a representative of the central fissure in non-primate animals, we shall see that this question can be answered in a positive manner.

We have upon many species a fissure, which comes from the f. calloso-marginalis, and which appears on the external surface—that is, the fissura cruciata. When we study the position of this fissure, we see that it lies in the anatomical and psychological sense in the anterior limit of the so-called psychomotor centres in the neighbourhood of the superior margin.

A transverse fissure, which could represent the central fissure, must therefore lie behind the cruciate fissure, and stand in the before-mentioned relation to the psychomotor centres. Such a transverse fissure we find on the anterior end of the first primitive fissure upon very many non-primate species, and it represents a more or less great part of the central fissure.

Before leaving the frontal lobe, I will try to answer still two

questions. The first is, has the human brain a representative of the fissura cruciata? We can affirm that really such a representative exists. On the inner surface of the hemisphere of the human brain exists an arcuate fissure, which represents the anterior limit of the paracentral lobe of Betz, and therefore it limits the so-called psychomotor centres in this part. It represents, therefore, that part of the fissura cruciata which lies on the inner surface. This anterior limiting fissure of the paracentral lobe of Betz is in some human brains in connection with the fissura calloso-marginalis, as in lower animals. A little transverse fissure on the outer surface of the brain limits generally the superior part of the anterior central gyrus from the anterior part of the frontal lobe, and this represents that part of the fissure which enters in the outer surface upon animals.

The second question is this: Does there exist on the human brain a representative of the fissura præsylvia of the lower animals? I am satisfied that such a fissure is present.

Anterior to the two well-known incisions of the fissura fossæ Sylvii into the frontal lobe, which are, if we might be allowed to call them so, the supports of the third frontal circonvolution, there exists upon atypical brains a third incision, which enters far into the frontal lobe, and which is curved often in the most anterior part in an upward direction. It separates the frontal from the orbital lobe.

This uncommonly complete fissure represents fully the præsylvian fissure of animals. In typical brains the fissure is most rare, but without connection with the fissura fossæ Sylvii, and it is very often separated in two, and even in three sections. It is known as the *fissura frontalis externa* of Wernicke. The superior and anterior part of the præsylvian fissure of animals may represent the sulcus frontalis medius indicated by Eberstaller upon the human brain (*Das Stirnhirn*, Wien and Leipzig, Urban and Schwarzenberg, 1890).

III. I may ask permission to make a little observation on that fissure, which separates in the middle basilar lobe the temporal lobe from the gyrus hippocampi. In many delineations of human brains by different authors this fissure

appears nearly rectilinear and regular. But, in fact, it is very irregular upon the brain of typical men, its anterior part being commonly in complete connection with the second temporal fissure and its posterior part often connected with the collateral fissure. Therefore, generally, the gyrus hippocampi seems better developed than in these cases, in which this fissure is rectilinear. In the last quoted cases this fissure is generally in connection with the collateral fissure, and penetrates sometimes through the fissura amygdalina of Wilder into the fissura fossæ Sylvii.

It seems to me that the "fine" development of the fissure is rather a peculiarity of atypical brains, and represents then a part of the limbical fissure of Broca limiting the gyrus hippocampi. I propose to call this fissure *fissura Broca*. I suspect that one has perhaps falsely spoken of an aplasia gyri hippocampi upon brains of epileptics. Upon the brains of atypical individuals this limbical fissure is very "regular," and the gyrus hippocampi seems therefore reduced.

IV. Allow me to develop very briefly before the English anatomists some of the mathematical views regarding anatomical and physiological conditions of the brain. The fundamental arithmetical law of anatomy and physiology of the brain is the *law of variation*, and not the law of addition or subtraction, as it is commonly assumed.

If we suppose that a muscle has acquired a new connection with one new cellule, and when this cellule is in direct combination with three cellules, and those three with fifty others, then the muscle can be used in 150 new combinations. Or, if we suppose that we acquire, through some nervous fibres and some cellules, the faculty to see certain thermical or chemical vibrations, and that this new organ is combined with the rest of the brain, then innumerable new combinations of conceptions, sentiments, and actions will be possible.

We see so that an increase of some centigrammata of substance and of some cubic centimetres can greatly multiply our psychological faculties. In the same way as a slight increase of connections with the periphery, also the evolution of a little central station of "relais" (*i.e.*, of a net of cellules united with

each other, and with the other parts of the brain) can infinitely multiply the power of the organ. It is by the help of such an "intercalated organ" that we enjoy the power of language.

V. Studying the skull with instruments and methods of precision, I recognised that the prophecy of Newton, that nature makes nothing but geometry, is fulfilled, and that we have reached the epoch in which we are able to search, or to begin to search, in our morphological studies for the geometrical laws of conformation, and to study by these laws the laws of the action of the formative powers. In other words, we have entered the epoch of the initial creation of bio-mechanics.

It will be profitable to consider some of these laws of increasing, and also to the advantage of anatomical questions of the brain.

A very general law in the biological world is, that conic and cylindric forms increase in such a way that the rectilinear cylinder becomes a cylindrical arch, that in the continuance of the increasing the axis represents a suit of arches, and that the tenons of subsequent arches form an angle which can even surpass 180°. In this way originate inflections, and also those of the three parts of the stem of the brain.

Another form of increase is that from the flanks of such a cylinder parts originate of an oblong or purely vesicular spherical form. From these spherical parts originate new forms of that sort, as is well known from embryological studies. In this way originate large gaps, open channels, and, as the spherical special parts approach each other, narrow fissures arise. We recognise so *one* of the *modi procedendi* of nature in the formation of fissures, and we must seek its mechanical reasons.[1]

When we see originate an elevation, we must recognise that in the direction of the greatest elevation the increasing power is the greatest, or the resistance the least, and it might be that generally both conditions are combined. On the limiting points of the basis of such an elevation, the increasing power must be the least, or the resistance the greatest, and also here both conditions can be combined. The resistance can be in-

[1] The theory of *Jelgersma* is not in opposition to my views, which consider the pure phenomenal part of the law of increase, and which seek to reconcile the views of Reichert and the important hydrostatical "reasons" of nature which have developed the first, with other theories (Engl. ed. of *Brains of Criminals*, p. 173).

trinsic or extrinsic. The external resistance can come from the surrounding tissues. I will not enter further in the discussion of this condition.

The internal conditions can arise from the fact that the original substance of the organ consists of two sorts of elements. In the one sort the increasing power is less, and its resistance against elevation is therefore greater.

We are sure, *f.e.*, by the studies of His on the medulla spinalis, that the original elements of the central organs of nerves are very soon separated into two sets in the epoch preceding the evolution of vessels. Some develop themselves into nervous elements, and the others to connective tissues. The latter at an early epoch has to fulfil the function of blood-vessels; it has to act the part of a nourishing tissue.

I lay down the hypothesis that the increasing power of this nourishing tissue is less, and its resistance for increasing greater, than is the case for the substantia propria organica. The evidence of this hypothesis is increased by the circumstance that the superior growth of specific substance seems to be characteristic of the time of youth, and the superiority of vitality of connective tissue for senility. In reality the fissures contain connective tissue, in which are developed in a later epoch the vessels.

If we consider specimens of injection, and then not only the surface of the fissures, but also the interior, we see really that the great vessels are in the depth of the fissures. I know that circumstance from fine specimens made by Betz, and demonstrated to me in my presence in Kiew. These specimens were called forth by my doctrine, that the ideas of fissures correspond to ideas of vessels. The anatomists believed that this doctrine is refuted by the fact that fissures exist before the existence of vessels. But we see the possibility that the representatives of vessels in the early epoch—namely, the nourishing connective tissue—can be at least the first reason for the condition which calls the fissures into existence. This arrangement of the arteries—one or two—in the depth of the fissures is of first-rate importance for the hydrostatic conditions, and for the functions of the brain.

If the arteries would enter into the brain from the meningeal

surface the branches ought to be larger, and then the brain would be exposed in a far greater degree to the pulsations and to the variations of pressure of the blood, and the brain-function would be far more dependent upon somatic conditions than is the case. The hydraulic art of nature surpasseth so far all human art and knowledge.[1]

We have spoken here of one of the manners in which fissures generate, and of the bio-mechanical reasons; but we are obliged to think always that biological equations cannot be thought sufficiently complicated. We must be aware that new complications are always found.

VI. In the conversation I had the honour to have with you at Berlin it was the question of auto-innervation of the brain which interested you highly, and as I suppose that the communications about it, which I made years ago (*Virchow's Archiv*, Bd. lix., 1873), are not known to the British anatomists, I wish to insist on them.

On a careful inspection of the fourth ventricle one sees little prominences in intimate connection with the plexus choroides. I supposed that these prominences represent flat nerves going from the medulla oblongata to the named plexus. The further exploration confirmed that supposition, and I found that those nerves finish on the blood-vessels, and go with very fine fibres to the epithelioid cells of the plexus.

We have therefore—(1) vasomotor nerves; (2) very similar secretory nerves, which, in a state of irritation, can increase the secretion of the named cells and produce hydrops ventriculi; (3) very similar nerves conducting irritation in a centripetal sense from the plexus choroides to the central part, and irradiate in the most different directions, and also in the direction of the vasomotor nerves of the plexus itself.

These nerves represent without doubt only a type of similar

[1] In an excellent book, the result of most exact anatomical inquiries—*Sulla coreccia cerebrale degli Equini et Bovini* (Parma, Lugi Batti, 1889)—the authors, Tenchini and Negrini, made the experiment to deduce from the distribution of arteries conclusions about the value of different parts of the brain. I don't consider this method a happy one; but as I saw at Berlin that this important book seems to have escaped the acquaintance of British authors, I recommend it on this occasion to them.

nerves, and I have reason to suspect that also the stria cornus contains such a nerve. This auto-innervation of the brain is of greatest importance for clinical science, and for all conclusions made from the clinical facts concerning physiological and anatomical conditions. I supposed always such a system by clinical want, before I could prove a part of it by the named research.

We have three forms of brain diseases, viz., (1) purely circumscribed ("focal") lesions; (2) diseases of "systems" in the sense of Flechsig; and (3) of diffuse diseases.

In the first series only the neoplasmata are in the beginning purely circumscribed affections, and the irritations by them follow only the laws of physiological irradiation.

Therefore I could already (1864),[1] and Ladame could pronounce (1865) the thesis, that convulsions are the only motor symptoms of cortical affections, and I declared at that time that every palsy in cortical affection be secondary "surexcitation" of sub-cortical motor centres.

Nevertheless, it happens that also neoplasmata call forth secondary affections of irritation, of atrophy, and sclerosis in parts, which are not in relation of contiguity and not in functional connection. Therefore, already in these cases I felt the want of a trophic connection by an unknown trophic nervous system.

I will observe here that every neurotrophic function cannot be considered as a single spasm or palsy of blood-vessels, but as a complicated proceeding. It was the study of the neuro-retinitis symptomatica which conducted me for the first time to the conclusion, that not only contiguity and functional connection are reasons of secondary affections, but that there must exist a neurotrophic mechanism.

In the cases of apoplexy, of acute softening, and in many cases of violent traumatism there appear in the beginning phenomena of shock, which must be localised in parts, which are not necessarily in relation of contiguity nor of functional connection.

These secondary phenomena can completely disappear, but we are generally not able to recognise this complete disappearance, and we draw false physiological conclusions regarding the

[1] See "*Medico-chirurg. Rundschau*," Wien, 1864, Bd. iv. pp. 84–95.

functions of the primary affected part, and of its connection with a certain anatomical system.

In that way there exist still renowned pathologists who accept a connection between the so-called psychomotor centres of the cortex, which I call the Hitzig-Betz centres, with the system of volitional movement, though the named centres have nothing to do with these functions. We know the pathological function of these centres, namely, the production of spasms, but one knows next to nothing about their psychological function.

In that way also the pyramids are generally regarded by pathologists, physiologists, and anatomists as a conducting system of volitional movements, principally because they undergo a secondary degeneration, in cases of hemiplegia, and I combat in vain, since twenty years, this fundamental error (see the paper "Zur Physiologie und Pathologie der Pyramiden," *Wiener Medic. Presse*, 1875, Vro 79).

Also, this secondary degeneration is to be considered as one which follows not the laws of contiguity and functional connection, but must be explained by the power of an unknown trophic mechanism, which must be a trophoneurotic.

In the "affections of systems" we observe also that there exists a tendency to be diffused, not only in the sense of contiguity and functional connections, but also with regard to these laws of the unknown trophic mechanism. We see from the pathological facts that there exists a general want of a trophic mechanism, which combines the different parts of the central system by "laws of diffusion" completely unknown, and it is a fundamental problem of anatomists to demonstrate this system. I yielded by the cited research only a little contribution to it. But every man must recognise that it is as well in science to be conscious of those facts and relations which are yet unknown, as of those which are known, to make not incomplete and partly false conclusions exclusively from that part of facts and relations which are known.

When I insist for a moment on a clinical question, it is because in questions of anatomy of the central nervous system the anatomist is so often dependent upon pathological facts. When we reproduce what was told here about the diffusion of

pathological processes, we must confess that we have to respect two great principles in diagnostics.

The first principle was developed in a typical way by Charles Bell, in his study of the affections of the facial nerve. It tells us to localise an affection there, where in a nerve, or in a conducting central system, or in a centre, are united all fibres, in which expansions exist are morbid symptoms. It is what I call *the diagnostical law of concentration.*

The second law, which I call *the diagnostical law of diffusion,* endeavours to seek out of the sum of the symptoms those which with security can be localised in certain parts ("focus"), and in certain systems, and to tell for certain symptoms and complications of symptoms, that their localisation at times is not possible.

I have developed these laws in my book, *Nervenpathologie und Elektrotherapie,* (1874–75, Leipzig), p. xxix. of the Introduction; but this representation was completely neglected by the profession, though really a clinician is every day in the position to respect it. The diagnostical law of diffusion is the empirical result of the law of diffusion of morbid processes.

FURTHER NOTES UPON THE CRANIA OF NORTH AMERICAN INDIANS. By R. W. SHUFELDT, M.D., C.M.Z.S., *Member of the Anthropological Society of Florence, Italy; the Anthropological Society of Washington, D.C., &c.*

IN volume xxii. of *The Journal of Anatomy*, the present writer published an article upon the "Comparative Data from 2000 Indian Crania in the United States Army Medical Museum," in which a classification of the various tribes of Indians of the United States was used, that was the official classification of the Institution referred to in the title of the article just quoted. A re-investigation of this subject leads me to believe that that classification is exceedingly crude and erroneous, and was the cause of errors in my work for which I was not wholly responsible. Not being content to allow it to stand as it was published, I have recently taken steps to rectify some of the most glaring mistakes in the matter of the taxonomy of the tribes, and with this end in view I submitted the article to my friend, Dr J. Owen Dorsey, than whom there is no better authority upon the kinships of a number of the tribes of Indians to which my article referred; which kinships or tribal relations are chiefly based upon the sound knowledge which he possesses of the various linguistic stocks. In a short time Dr Dorsey kindly sent me a very valuable letter upon this subject, dated October 15, 1890, with his permission to publish it in connection with such observations as I pleased to make in the present "Notes." The letter reads as follows:—

"I have examined with interest your paper entitled 'Comparative Data from 2000 Indian Crania in the United States Army Medical Museum,' and according to my promise I send you the following remarks:—

"On p. 194 I find Shoshone Indians and Snake Indians recorded as if they were distinct tribes; but they are two names for the same people (see Nos. 19 and 20). To this Shoshonian linguistic stock belong Nos. 23, 24, and 25 on p. 195, the Ocki Pah Ute, Pah Ute, and Utah Indians.

"The following belong to the Athapascan Stock:—No. 32, Navajo

Indians, and No. 33, Apache Indians, both on p. 196; No. 34, Hare Indians, on p. 197; and Lipan Indians, No 73, on p. 200.

"The following belong to the Caddoan stock:—No. 39, Arickaree Indians, on p. 197; Caddo Indians, No. 53, on p. 199; Pawnee Indians, No. 56, on the same page; Wishitaw Indians, No. 65, on the same page; Iowaulkeno (*sic*) Indians, No. 69 on p. 200—this should be To'-wa-ka'-re-hu, "Three Canes," a clan of the Wichita tribe, sometimes called To-woc-co-nie; Kechi Indians, No. 70, on p. 200.

"SIOUAN STOCK.

"Sioux, No. 41, on p. 197, is identical in meaning with Dakota, No. 50, on p. 198. Dakota is the national name, Sioux being an abbreviation of a Canadian French corruption of an Algonkian name for the Dakotas, Nadowessiwag, the snake-like ones, the enemies. With which compare the eastern Nottoway.

"Divisions of the Dakotas or Sioux:—Santee, No. 46, p. 198; Sissiton, No. 45, same page; Wahpeton, No. 48, same page; Yankton, No. 44, same page; Teton, No. 47, same page, has seven divisions, among which are Brule, No. 42, on p. 197; and O-gla-la ("Ogalalla"), No. 43 on p. 198. Assiniboine, No. 40, p. 197 (an offshoot of the Yanktonnais Dakotas).

"Tribes of the Siouan stock, but not part of the Dakotas:—Mandan, No. 38, p. 197; Hidatsa or Minnetarree, No. 54, on p. 199. Closely related to them are the Crows, No. 52, on p. 198.

"Closely related to the Mandan are the Winnebago, No. 55, p. 199.

"The Ponka, No. 51, p. 198; the Kaw, No. 60, p. 199; and the Osage, No. 63, p. 199, belong to the Dhe'-gi-ha group of the Siouan stock, and have many words in common.

"Menominee *Sioux*, p. 205, a misprint, as the Menominee belong to another stock.

"*Undesigned Coincidences.*—On p. 210, lines 13, 14, Dakotas and Ponkas are both Siouan. So at the bottom of that page, and Mandans, at the top of p. 211.

"P. 211, lines 25, 26.—Apache and Mojave Apache, same stock.

"P. 212, lines 21, 22—Wahpeton Sioux and Mandan, same stock.

"The names 'Californian Indians,' 'Nevada Indians,' 'Oregon Indians,' &c., are too vague, as different linguistic stocks inhabited those states."

These corrections are so clear that there will be no difficulty in comprehending them, when duly referred to the original article. Especial attention is invited to what Dr Dorsey designates as "undesigned coincidences,"—for as such they surely lend greater strength to the deductions from the data than anything else could have done. Very justly a shade of suspicion is thrown over the data derived from such tribes as were designated in the "Otis List"—as Californian Indians, Nevada Indians, Oregon Indians, &c., for the reasons that are stated.

Considerable progress has been made during the past few years in our knowledge of the true affinities of our many and widely scattered tribes of North American Indians. Much yet remains, however, to be unravelled, and there is a great deal that has passed into the realm of the never-to-be-known. Now, more than ever, the greatest dispatch is required to collect all manner of data that refers to our Indians, for many of the so-called tribes are mere miserable remnants of their former numbers. We have instances where a tribe is now represented by perhaps less than 200 individuals all told. With nearly all, civilisation closely crowds them, so that the purity of their language, their myths, their simple industries, are becoming rapidly adulterated and irrevocably changed. By inter-marriage, even the very Indians themselves are changing, so it goes without the saying what the fate of some must very soon be.

Under these circumstances it behoves the human craniologists in general, and of this country in particular, to make all haste to collect good, reliable skulls of the representatives of the various tribes,—for at the best there is always a shadow of suspicion attached to the data obtained from large collections of skulls of savage races of peoples, low in the scale of intellectual advancement. I am sceptical enough to say that there is generally abundant ground for this. In any event, to have any value attached to the data, cranial capacities and other measurements of the skull *must* rest upon *averages* taken from *long series*, and those only from crania where the full histories are known, such as the *purity of the stock*, the *age* and *sex* of the individual, and, if possible, something of the mental capacities in each case.

POLYMASTISM, WITH SPECIAL REFERENCE TO MAMMÆ ERRATICÆ AND THE DEVELOPMENT OF NEOPLASMS FROM SUPERNUMERARY MAMMARY STRUCTURES. By W. Roger Williams, F.R.C.S., *Surgeon to the Western General Dispensary, late Surgical Registrar, Middlesex Hospital.*

Section 1.

The human breasts (*mammæ*), like those of all other Mammalia, are generally regarded as greatly enlarged and modified cutaneous sebaceous glands.

The observations of Dr Champneys [1] on the development of mammary functions by the axillary sebaceous glands of women during lactation, as well as those of Duval [2] on the nature of the secretion of the acinous glands of the areola under like conditions, show that the difference between sebum and milk is only one of degree.

In all this it appears to me there is nothing to countenance the extraordinary view recently advanced, that in human beings highly specialised organs like mammæ and teeth, which have taken immense ages to attain their present degrees of perfection, can be suddenly evolved, as "*sports*," from ordinary sebaceous glands and cutaneous epithelial processes respectively.

I must offer emphatic protest against this assumption, which is a contravention of the fundamental principle of *heredity;* and I shall presently show that the evidence on which it is based is altogether delusive.

Like all other glands opening on the free surface of the body, the mamma is developed from the columnar cells of the epidermis, by a process of continuously progressive ingrowing gemmation, with differentiation.

The question has arisen whether the mamma is to be regarded as the homologue of a single sebaceous gland, or of an aggrega-

[1] *Med.-Chir. Trans.*, vol. lxix. (1886), p. 419.

[2] *Du Mamelon et de son Auréole*, Thèse de Paris, 1861, p. 43.

tion of such glands. It appears to me that the only reliable guide in this matter is the ontogeny of the organ. Inasmuch as all observers are now agreed that the mamma is developed from but a *single* epithelial ingrowth; and that the form ultimately attained, in which the gland discharges by numerous ducts on the summit of the nipple, is due to secondary modification (kenogenesis): I am decidedly of opinion that the mamma is the homologue of but a single sebaceous gland.

The nipples (*mammillæ*)—papilla-like outgrowths adapted for being sucked—do not develop until after the glandular elements have been formed; and sometimes they never arise.[1] These ontogenetical phenomena are of great interest from the standpoint of phylogeny, because the lowest mammalian animals—the Monotremata—have no nipples. In them the milk simply emerges by numerous ducts, through a sieve-like perforated patch of the abdominal skin, from which the young animals have to lick it. These ducts open either on a flat surface (*Ornithorhynchus*), or into a pouch of the integument (*Echidna*). From this it may be inferred—inasmuch as the ontogeny of organs generally represents and accords with their phylogeny—that our mammalian progenitors had no nipples, though they had the glands.

The marsupials differ from the monotremes in possessing nipples. According to Darwin[2] these structures were first acquired by marsupials after they had diverged from and risen above the monotremes, and were by them transmitted to the placental mammals.

In human beings, at an early stage of development, the site where the nipple will subsequently appear is marked by a depression, towards the bottom of which the ducts of the gland converge. This rudimentary state may persist throughout life; such malformations are met with both in the normally placed and in the supernumerary nipples. They recall the mammary pouch of *Echidna*.

The further development of the nipple is effected by the

[1] Chambers, *Obstet. Soc. Trans.*, vol. xxi. (1879) p. 256; De Sinéty, *Traité de Gynécol.* (1884), p. 946; Duval, *Op. cit.*, p. 98; Cruveilhier, *Traité d'Anat. Descript.*, ed. 1874, t. ii. p. 525; Davis, *Med. Times* (1852), vol. i. p. 250.

[2] *Descent of Man* (1879), p. 162.

area of skin perforated by the ducts, being raised up into the form of a papilla, above the level of the rest of the integument.

When the whole of the cutaneous area perforated by the ducts of the nascent gland is not integrated with the developing nipple, then such of the ducts as are left behind, instead of opening on the summit of the nipple, do so on the areola, where several of them are usually to be found, chiefly about the base of the nipple.[1] Thus the *glandulæ lactiferæ aberrantes* arise. From the frequency of these and other similar malformations, it may be concluded that the mammæ, like the lachrymal and salivary glands, are normally very imperfectly integrated organs.

SECTION 2.

Human beings usually have but a single pair of mammary glands, which are situated on the ventral aspect of the thorax (*pectoral*), as in Apes, Bats, Elephants, and a few other mammals. This is the smallest number normally met with throughout the group. Most mammals have several pairs of such glands, situated at various points of the ventral surface of the trunk; and, as a rule, there is a certain relation between their number and the number of young brought forth at a birth, the former being twice as numerous as the latter.

In the insectiverous order, which yields the largest number, there may be as many as eleven pairs, and there are seldom fewer than seven. In these cases the glands extend along the whole length of the ventral surface, in two nearly parallel rows, from the axillary to the inguinal regions. I said *nearly* parallel, because the two rows converge towards the inguinal regions.

In the lowest mammalians (monotremes, marsupials, &c.)—which represent the primitive type—the mammæ are as a rule exclusively inguinal; in the highest class they are almost invariably pectoral; whilst animals with abdominal mammæ occupy an intermediate position.

In human beings any diminution of the normal number is very exceptional; but it is by no means uncommon to find their number increased. When this does occur, it is a significant fact that the additional mammary structures do not develop just

[1] Sappey, *Traité d'Anat. Descript.*, t. iv. (1874), p. 770.

anywhere; but they appear only in certain definite positions, which almost invariably correspond with those occupied normally by the glands of polymastic animals.

Such facts warrant us in attributing their origin to reversion; and they imply the existence in the past of a polymastic *atavus*, accustomed to produce several young at a birth.

The transition from polymastism to bimastism may now be seen going on in the Lemurs, whose inguinal and abdominal mammæ are aborting, so that only a single pair of pectoral ones tends to be well developed; and this change has evidently been induced by diminution of the number of young brought forth at a birth.

Similarly in many marsupials it has been observed that more nipples are found in the fœtal than in the adult state: some of these structures atrophy, whilst others develop.

"On the whole," says Darwin,[1] "we may doubt if additional mammæ would ever have been developed in both sexes of mankind, had not man's early progenitors been provided with more than a single pair."

I think it would conduce much to a more complete understanding of the subject if I could give a sketch of the mammary arrangement of these early progenitors.

According to Meckel von Hemsbach, human beings originally had five mammæ: a pair corresponding to the normal pectoral ones, one in each axilla, and a median one just below the sternum.

I suppose the author must have based this idea of his on some cases he had seen, in which the glands really had this distribution; but I have been unable to find the record of any such case. Modern investigations have discredited this conception of Meckel's.

In the numerous well-recorded cases of supernumerary mammary structures now available, there are ample materials for reconstructing the mammary arrangement of the ideal human *atavus* on a really scientific basis. From this source it may be gathered that our early progenitors had at least seven pairs of mammæ on the ventral aspect of the trunk; of these only the present pectoral pair have survived. Of the six lost pairs, three

[1] *Op. cit.*, p. 37.

were situated above and external to the present normal pair, and three below and internal to them (fig. 1).

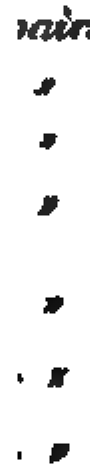

FIG. 1.—Diagram showing the mammary arrangement of man's early progenitors.

On careful consideration of all the facts known to me relative to the distribution of mammæ in human beings and animals under normal and abnormal conditions, I find it impossible to come to any other conclusion than that the mammæ were originally *segmental organs*—a pair being developed on the ventral aspect of each *somite.* In confirmation of this view the following cases may be cited:—

In *Neugebauer's* case, with eight supernumerary nipples, the largest number yet observed in any human being, three pairs were situated above the normal mammæ, in positions identical with those figured in my diagram. The other two nipples were situated below, and internal to the normal pair; that on the right side was placed imme-

diately below the bosom, that on the left side was some inches *lower down.* These unsymmetrical nipples must *not* be regarded as a pair; the upper one evidently represents the right nipple of the fifth pair of my diagram, and the lower one the left nipple of my sixth pair.

In *Fitzgibbon's* case, two pairs of supernumerary nipples were present; one pair above the normal mammæ correspond to the third pair of my diagram; and the other pair, below the normal, answers to my fifth pair.

In *Mortillet's* case, two pairs of supernumerary nipples were also present, but both were situated below the normal breasts; the lower pair occupied the upper part of the *abdomen,* in a position which corresponds with the seventh pair of my diagram; the upper pair was situated between the normal mammæ and the abdominal pair, probably in the position of the fifth pair of my diagram, but as to this the author's description lacks definition.

The other cases of supernumerary mammary structures occupying positions corresponding to those figured in my diagram, may be classed as follows:—

First pair (axillary), cases by Leichtenstern, D'Outrepont, Perreymond, &c.

Second pair (middle of anterior axillary border), cases by Quinquad and Bruce.

Third pair (just above and slightly external to the normal female bosom), cases by Shannon (fig. 3), Lee, Gardiner, and Champneys.

Fourth pair (the normal mammæ).

Fifth pair (just below and slightly internal to the normal female bosom). More than three-fourths of all instances of supernumerary mammary structures have been found in this position. Typical examples of the development of this pair of mammæ in women have been recorded by Leichtenstern (fig. 2), Whitford, and many others; and in men by Max Bartels, Handyside, &c.

Sixth pair (below and slightly internal to the preceding, near the costal margin), cases in men by Leichtenstern and Hamy, and in women by Rapin, De Sinéty, &c.

Seventh pair (below and slightly internal to the preceding, on the upper part of the *abdomen*). Cases by Tarnier, Bartholin, and Bruce.

Further on details will be given of all the cases above referred to.

Supernumerary mammæ appearing in any of the above positions must, for the reasons before mentioned, undoubtedly be regarded as true reversions.

Section 3.

It is an exceedingly rare thing for redundant mammary structures to be found in any other part of the body. Of 166

cases collected by Leichtenstern[1] and Bruce,[2] there were only four instances of this kind (*mammæ erraticæ*), and they are probably rarer even than this.

I now propose to examine these cases, and other similar ones since recorded, with a view to determining their real significance.

Considering the great similarity between the condition resulting from chronic fistula in connection with sebaceous and dermoid cysts that have undergone suppuration, which extends even to the production of a milk-like fluid, and several of the alleged cases of *mammæ erraticæ*, I think the latter ought to be very critically examined before they are definitively accepted as such.

These remarks are especially applicable to the two cases of so-called *dorsal mammæ*, of which the records are ancient and very imperfect. For instance, all the information we have of the case mentioned by Paulinus,[3] is as follows:—

"Rustica fœmina e comitatu Winzemborch præter duas in loco ordinario adhuc duas alias ejusdem quantitatis et qualitatis mammas lacte fœcundas, habuit e regione in tergo. Jam tertia vice peperat, gemellos, qui ante retroque suxerunt."

The account of Helbig's[4] case is still more unsatisfactory.

"B. Salewsky, nobilis Polonus, vir fide dignus in insula Macassar (veteribus celebes) mulierem vidit quæ mammas duas in dorso habens, eas sub axillis protractas infanti dabat et firmiter asserebat integro consanguinearum suarum numero hanc monstrositatem esse propriam."

It is very well for such cases to be in the mind of the artist; but until confirmed by modern observation they ought not to be admitted into the art itself.

In this connection it may be well to recal the fact that in a few animals the mammæ normally have a dorsal position; *e.g.*, *Myopotamus coypus*[5] (near the dorsal spine), *Capromys*

[1] *Arch. f. Path. Anat.*, Bd. 73 (1878), s. 222.

[2] *Journal of Anatomy*, vol. xiii. (1879), p. 425.

[3] "Obs. medico-phys. select," in the *Miscel. Curios. Acad. med. phys. nat. curios.*, an. iv. p. 203, in the appendix.

[4] *Op. cit.*, an. ix. and x. p. 456.

[5] *Proc. Zool. Soc.* (Christy), 1835, p. 182.

fournieri[1] (behind each axilla), and *Lagostomus trichodactylus* (dorso-lateral aspect of thorax).

Barth[2] has recorded a very remarkable case of alleged "*mamma erratica*" on the face.

The patient was a slender blonde, aged 20, who had, just in front of the lower part of her right ear, a peculiar wart-like growth surrounded by pigment and a few hairs. It was erectile, and looked very like a nipple. The patient said it generally enlarged during menstruation, and that it had existed as long as she could remember. She had a somewhat similar growth, which also enlarged during menstruation, above her nose; and several pigment spots on various parts of the face, as well as a large one at the lower edge of the right breast. The nipple-like growth on the face was excised. On *microscopic examination* it was found to consist chiefly of sebaceous gland tissue, which was *not* embedded in the subcutaneous fat. In several of the sections small epithelial pearls were seen, and cellular collections like small sebaceous cysts; as well as irregularly arranged groups of sweat glands, and bundles of unstriated muscle fibres. A few ducts were observed, but none could be traced to the nipple-like process. Waldeyer, who examined the histological preparations, advised giving no positive opinion as to the real nature of the disease; and the title of Barth's essay, *Eine eigenthümliche Warze nahe der Ohrmuschel*, suggests that the author himself was in doubt.

I have several times seen similar histological appearances in connection with congenital malformations of the skin of the face (warty moles); and I am inclined to regard the case as belonging to this category, rather than to that of "*mamma erratica.*"

The case of accessory mamma *near the acromion*, recorded by Klob,[3] may be regarded as an unusual form of reversion; for, as Beddard[4] has shown, in *Hapalemur griseus*, mammæ are of normal occurrence in this locality; as they are also in certain pachystomatous Cheiroptera.[5] In one of Champney's[6] cases, a lying-in woman had a supernumerary mamma in each axilla, the size of a pigeon's egg, which opened by a single pore at the middle of the anterior axillary fold. From the gland in the right axilla *a tail was prolonged down the arm for nearly an inch.*

Klob's patient was a man, and the supernumerary gland pre-

[1] Cuvier, G., *Leçons d'Anat. Comp.*, t. viii. p. 606 (leçon 38e).

[2] *Arch. f. Path. Anat.*, Bd. 112 (1888), s. 569.

[3] *Zeitschr. d. K. K. Gesellsch. d. Aerzte z. Wien* (1858), N.F.I., No. 52, s. 815.

[4] *Proc. Zool. Soc.*, 1884. p. 394. Although the specimen to which the description relates is a male, well-developed mammary glands were found to exist. The apertures of these glands were upon the upper part of the arm; and, on removing the skin, the glands themselves were found to be attached by membrane to the *pectoralis major*, the *biceps*, and part of the *deltoid* muscles.

[5] Milne-Edwards, H., *Leçons sur l'anat. comp.*, &c., t. ix. (1870), p. 132.

[6] *Op. cit.*, p. 434.

sented as a conical swelling, the size of a walnut, just below the left acromion, over the convexity of the deltoid muscle. It had a rudimentary nipple, but no areola. *Microscopic examination* revealed acinous gland tissue like that of the normal mamma.

Puech[1] refers to a case by Scalzi, from an Italian source, in which an aged woman, who was admitted into hospital for a scalp wound, was found to have a rudimentary supernumerary mamma on the right shoulder, near the axilla, and another below the left breast. Her daughter had a supernumerary milk-giving mamma.

An analogous case, in the lower limb, has been recorded by Robert of Marseilles.

The patient was a woman, aged 50, with a supernumerary milk-giving mamma on *the outer side of the upper part of the left thigh*, 4 inches below the great trochanter.

The case was examined and reported upon by Magendie,[2] for the French Academy of Science.

The real nature of the supernumerary gland was only discovered after her first confinement, when it attained the size of half a lemon, and secreted milk.

She had previously noticed in this situation, "un petit corps arrondi qui a toujours été le siége de douleurs et de démangeaisons, commes les seins mêmes aux époques de ses règles." The gland had a nipple, like the normal ones, so that she could suckle her children as well with it as with them. Strange to relate this woman's mother had a supernumerary pectoral mamma on the right side.

The position of the redundant gland in this case reminds us of the so-called *glandula femoralis* of the male *Ornithorhynchus*; of *Capromys fournieri*, which has, in addition to a mamma behind each axilla, two others "en avant des cuisses, tout à fait sur le côté et plus prés du dos que du ventre;"[3] and of the *Mare* and *Ass*, which have the mammæ in the groins, far in front of the vulva.

Here also it seems tolerably certain that we have to do with an aberrant form of reversion.

The above case has often been erroneously cited as an example of *inguinal* mamma—a condition which, according to Leichtenstern, has never been observed in any human being.

Not long since, however, Blanchard[4] referred to an unpublished case of Professor Testut's, in which this anomaly was met with. It occurred in a woman in the lying-in hospital of Bordeaux. She had a true supernumerary mamma on the antero-internal aspect of the right thigh, a short distance below the fold of the groin. During lactation this gland increased in size and secreted milk freely. I have not met with the detailed account promised by M. Testut, but, for the sake of science, I hope it will be forthcoming.

As previously mentioned mammæ exclusively inguinal are typical

[1] Puech, *Les mamellis et leurs anomalies*, Paris, 1876, pp. 72 and 117.

[2] *Jour. Gen. de Méd.*, t. c. (1827), p. 57.

[3] Milne-Edwards, *Op. cit.*, p. 132.

[4] *Bull. de la Soc. d'Anthropologie*, t. viii. (1885), p. 230.

of the lowest mammalian orders. Among the highest orders rudimentary inguinal mammæ are occasionally present, as in the *Rhinolophidæ*, although all other Cheiroptera have long since lost all trace of their inguinal mammæ. In some Lemurs, in the Aye-Aye, and in many other animals, mammæ are of normal occurrence in the inguinal regions. The above case seems to indicate that in human beings reversion may occasionally reproduce this very ancient ancestral mammary arrangement.

Hartung's[1] case is evidently nearly allied to the foregoing. Here a supernumerary mamma was situated in the *left labium majus*. The patient, a woman aged 30, who was suckling her child, had a pedunculated tumour, the size of a large goose's egg, attached to the lower and inner part of the *left labium majus*. It was covered over with skin, and its pedicle was the size of a man's thumb. In front, at its upper part, there was an eroded ovoid patch, from which milk-like fluid escaped. The patient said she had noticed the tumour for several years; and that it had lately got much larger. It was freely excised with the pedicle, and during the operation a considerable quantity of milky fluid escaped.

On examination after removal, a flattened rounded prominence, like a retracted nipple, could be made out in the centre of the eroded area; and surrounding this was a shallow depression. At the summit of this prominence were several small orifices, some of which admitted a probe; they were ducts which radiated into the tumour substance. It was obviously a rudimentary malformed nipple, with its areola. The rest of the tumour consisted of two gland-like masses, the smaller one about the size of a walnut; on *microscopic examination* these were seen to be composed of acinous glandular structure, lined with sub-cylindrical epithelium, just like that of the normal mamma. In the region of the rudimentary nipple were numerous ducts lined with cubical epithelium. The pedicle consisted of fibro-fatty tissue and vessels. From the careful description given of this case it seems impossible to doubt that we here have to do with a true supernumerary mamma.

In most *Cetaceans* the mammæ normally occupy a somewhat similar position; and a little insectivorous animal (*Sorex crassicaudatus*), in addition to two pairs in the groins, has a third pair under the base of the tail, at the level of the anus.[2]

In three cases rudimentary mammæ have been found in the *median* line of the front of the body.

Gorré[3] refers to a Wallachian *vivandière*, the mother of two children, who died shortly after the birth of her second child from the effects of exposure and privation. On examining her body after death, Gorré was surprised to find a well-developed pair of supernumerary milk-giving mammæ, situated below and internal to the normal ones; and between these a rudimentary median one, five inches above the umbilicus.

[1] *Ueber einen Fall von Mamma Accessoria*, Inaug. Diss., Erlangen, 1875.

[2] Cuvier, *Op. cit.*, p. 606.

[3] *Dict. des. Sci. Méd.* (1819), t. xxxiv. p. 529.

Max Bartels[1] alludes to an instance of similar malformation in a man.

In the other case[2] an exceedingly beautiful lady, the mother of five well-formed children, had a small rudimentary median mamma rather below the level of the normal glands.

Median mammæ are very rare in the animal world; but instances occur in the Virginian Opossum (*Didelphys virginiana*), and in a few other marsupials.

From the foregoing remarks it will be gathered that I regard the so-called *mammæ erraticæ* as due to reversion to ancestral arrangements much more ancient than those reproduced in ordinary cases of polymastia.

There is no evidence whatever that such structures can arise just anywhere, as "sports," from ordinary sebaceous follicles; on the contrary, I have shown that they only arise in positions which correspond with those occupied normally by the glands of polymastic animals.

My investigations prove that highly specialised structures like the mammary gland, with its nipple and appendages, never develop suddenly in any human being, except in response to ancestral hereditary influence. Were it otherwise, human beings would have even more mammæ than Diana of Ephesus.

We know that supernumerary teeth, like supernumerary mammæ, are occasionally met with in mankind. But these redundant teeth do not occur just anywhere on the general cutaneous surface, but only in certain regions of the mouth hereditarily predisposed to reproduce them.

Supernumerary mammæ are frequently found on the general cutaneous surface of the front of the trunk, but teeth never. What is the reason of this? The answer is, that our remote ancestors were accustomed to have mammæ developed there, but not teeth.

It will be advanced as an objection to this reasoning that *supernumerary mammæ and teeth* have been found *in the walls of ovarian dermoid cysts.*[3] I willingly answer this objec-

[1] Reichert and Du Bois Reymond, *Arch. für Anat.*, &c., 1872, p. 306.

[2] Percy, "Mém. sur les femmes multimammæ," *Jour. de Méd. de Corvisart*, An. xiii., t. ix. p. 381.

[3] Corradi, A., *Dell Ostetrica in Italia*, Bologna, 1874, p. 1459; Haffter, E., *Arch. f. Heilk.* 1875, s. 56; *Arch. f. Path. Anat.* (Velitz), Bd. 107, s. 505; *Trans. Path. Soc. Lond.* (Sutton and Shattock), vol. xxxiv. pp. 437, 442.

tion, as it will afford me an opportunity of refuting the erroneous interpretation that has lately sprung up as to the origin of these remarkable anomalies.

The current view, which ascribes the origin of most ovarian dermoid cysts to sequestration of a portion of the cutaneous matrix, at an early stage of development, enables us to understand the presence of hairs, sebaceous follicles, sweat glands, and other normal dermal structures in the walls of such cysts.

Since it may very well happen, during the process of sequestration, that portions of the matrix of adjacent structures may also be involved, we can understand on this hypothesis how it is that connective and fatty tissues may be found in connection with such cysts, and even pieces of bone and cartilage.

But when in the walls of congenital ovarian cysts we find highly specialised structures, like mammæ and teeth, which are never produced in the normal ontogeny by any portion of skin likely to be thus sequestrated, this hypothesis is, I maintain, no longer tenable.

In these cases, I believe, we have to do with very imperfect parasitic fœtuses *per inclusionem,* in which only the mammæ or teeth of the parasite have survived.

Many examples [1] of this monstrosity have been recorded, in which only a single part or organ of the parasite has developed. In a case lately published by Kümmel,[2] there was only a rudimentary eye.

The cases of cows with udders on the back and supernumerary extremities also belong to this category.[3]

SECTION 4.

Mammary anomalies *per excessum* were formerly regarded as great rarities, because the old observers noticed only very

[1] Lannelongue, *Traité der Kystes Congénitaux,* 1886, pp. 236–256.

[2] *Arch. f. Path. Anat.*, Bd. 118, Heft 1.

[3] Bugnion has recently described, in the *Revue Méd. de la Suisse Romande* (1889, p. 334), the case of a woman with a parasitic monstrosity, consisting of pelvis and lower extremities, which was attached by its rudimentary pelvis to her pubic region. In each groin she had a nipple-like process, surrounded by a pigmented area, which represented the mammæ of the *parasite.* The woman herself was otherwise well formed.

marked examples, to which their attention was usually drawn by the escape of milk from the tumour. Hence most of their cases were in women—pregnant or recently confined.

According to Bruce,[1] of 315 individuals of both sexes, taken indiscriminately, 7·6 per cent. presented the malformation; of 207 males, it was present in 9·1 per cent.; and of 104 females, in 4·8 per cent.

It is therefore nearly twice as frequent in males as in females.

Herein it resembles most other congenital malformations, which, as I have shown,[2] are much commoner in the male than in the female sex.

In this connection it is interesting to recall the observations of Darwin,[3] as to the great proneness of secondary sexual characters to vary, especially in males.

Supernumerary mammary structures very rarely attain the structural and functional completeness of the normal glands; as in the case of a woman described by Tarnier,[4] who had an extra pair of abdominal mammæ which equalled the normal ones in every respect.

It is usual to find the supernumerary organ represented only by a nipple—with or without its areola (true polythelia).[5]

In other instances there is neither nipple nor areola, but simply a subcutaneous mass of glandular tissue, which may communicate with the surface of the body by one or several pores, or be altogether cut off from it (true polymastia). Between these varying structural grades all kinds of intermediate conditions are met with.

In its least degree, the malformation *per excessum* is represented by the bifid nipple.

Duval[6] says, "I have seen a young woman, 25 years old, who had the nipple of each breast divided nearly to its base into two equal parts. She said her nipples had been thus from birth. The deformity did not interfere with lactation."

[1] *Journal of Anatomy*, vol. xiii. p. 423.
[2] *The Influence of Sex in Disease*, Churchill (1882), p. 4.
[3] *Descent of Man* (1879), p. 228 *et seq.*
[4] *Traité de l'art des Accouch*, Par Cazeaux, 8me ed. (1870), p. 86.
[5] θηλή = nipple.
[6] Duval, *Du Mamelon et de son auréole*, Paris (1861), p. 90.

Slight exaggeration here leads to the formation of two nipples on one areola (intra-areolar polythelia), as in a case described and figured by Tiedemann.[1]

In this case the drawing was made from the body of a girl in the dissecting room, on each of whose otherwise well-formed breasts two nipples were found within one areola—one nipple perpendicularly below the other.

In other cases one or more supernumerary nipples, each with its own areola, are met with, in various positions, on a single being breast (intra-mammary polythelia).[2]

Percy and Laurent,[3] in their clever essay, have related a remarkable case of this kind. The patient was a woman who had two large pectoral mammæ in the normal position, of which the left was furnished with five nipples, each with its own areola, and the right with two nipples, also with distinct areolæ.

Prackel[4] saw a Scotch woman with three nipples on each breast, arranged so that they corresponded to the angles of an equilateral triangle, the two additional ones being below the normal nipple. Each of them gave milk. The woman had given birth to twins several times.

De Sinéty[5] and Tarnier[6] have each related a case of intra-mammary polythelia in women whose mothers had identical malformations.

A most remarkable instance of the inheritance of this deformity has been recorded by Blanchard.[7]

A man, the father of thirteen children—seven males and six females—had a supernumerary nipple with a rudimentary areola on each breast, a few cm. below each normal nipple (intra-mammary polythelia). All his seven sons had the like deformity, but none of his daughters. The youngest of the sons is the father of five children—four boys and one girl. All the boys have supernumerary nipples like their father, grandfather, and six uncles.

These anomalies arise from excessive growth of the rudiment of the gland and nipple, after the developmental process has made a certain amount of progress; consequently the causes which determine them must be referred to a much later stage

[1] Tiedemann and Treviranus, *Untersuchung über die Nat. der Mensch.*, &c. (1831), Bd. v. s. 110, taf. i. fig. 3.

[2] Duval, *Op. cit.*, p. 83 *et seq.*; Engeström, O., *Arch. de Gynéc.*, t. 31, p. 282; Chowne, *Lancet*, vol. ii. 1842, p. 465; Puech, *Op. cit.*, p. 84.

[3] *Dict. des Sci. Méd.* (1819), t. 34, p. 525.

[4] *Miscell. Curios. &c.*, *Dec.* ii., *Ann.* v., *App. Obs.* 67, p. 40.

[5] *Gaz. Méd. de Paris* (1887), p. 317.

[6] Cazeaux, *Traité de l'art des Accouch*, 8e ed. (1870), p. 86.

[7] *Bull. de la Soc. d'Anthropologie*, t. ix. (1886), p. 485.

of embryonic development than those which determine atavistic supernumerary mammæ. That is to say, the causes of these malformations are of the same nature as those which originate *discontinuous growth* in general.

From such conditions, which are relatively rare, I will now pass to those much commoner ones, in which the supernumerary mammary structures are quite independent of the normal breasts.

The number of these supernumerary parts may vary from one to eight; but more than two are very exceptional.

Of Leichtenstern and Bruce's 166 cases, in 112, or two-thirds, there was only a *single* extra structure.

Such single redundant mammary structures are almost invariably situated a little below and internal to the corresponding normal mammæ, in the position of the fifth pair of my diagram (fig. 1); and they are much more frequently seen on the left than on the right side.[1] In women I have found that cancer[2] and other mammary neoplasms[3] have also a much greater predilection for the left than for the right mamma; but I have not observed the same disproportion in males.[4]

The like relation holds with regard to this anomaly, for on separating the sexes I have found that, of 42 males in Bruce's list, the deformity occurred on the left side in 22, and on the right in 20.

A small proportion of these single extra mammary structures are met with lower down than the above, in a position corresponding to that occupied by the sixth pair of my diagram. Both Leichtenstern and Bruce have recorded several such cases.

In the great majority of the remaining cases there was present a pair of supernumerary mammary structures, situated a little below and internal to the normal glands, in the position of the fifth pair of my diagram (fig. 1).

Typical instances of this kind in women have been recorded

[1] Of 101 single cases in Leichtenstern and Bruce's lists, 64 were on the left side, and only 37 on the right.

[2] *Middlesex Hospital Surgical Report* (1888), by the Author, p. 87.

[3] *Ibid.* (1889), Table v.

[4] *Lancet* (1889), vol. i. p. 262.

by Leichtenstern,[1] Whitford,[2] and many others; and in men by Bartels,[3] Handyside,[4] &c.

In Leichtenstern's case (fig. 2) the patient was a healthy young woman with a redundant pair of small, erectile, symmetrical nipples, each surrounded by a pigmented areola, situated just below and internal to the normal mammæ.

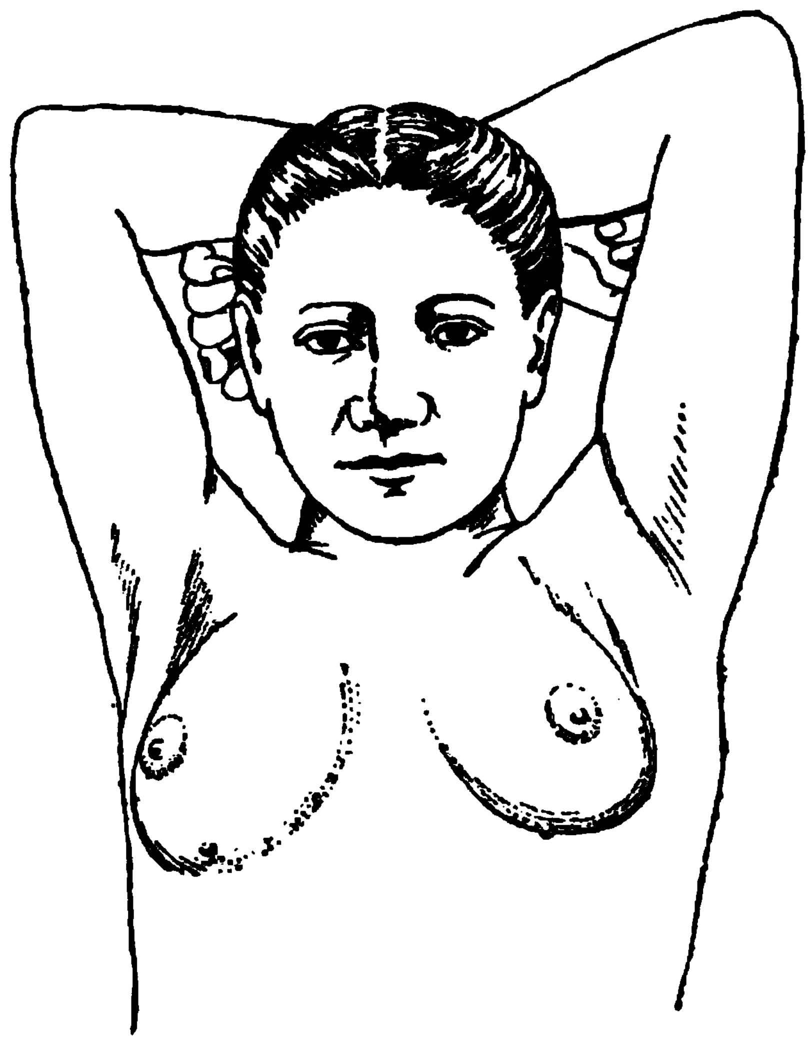

Fig. 2.

More than three-fourths of all cases of supernumerary mammæ have been found in this situation, on one or both sides.

We may conclude from this that our progenitors had a redundant pair of mammæ here long after they had lost all their other supernumerary glands.

In some *Lemurs* a similarly placed second pair of pectoral mammæ is still of normal occurrence.

In a certain number of cases a supernumerary *pair* of mammæ has been found below and internal to the above, in the position of the sixth pair of my diagram (fig. 1). Typical instances of

[1] *Arch. f. Path. Anat.*, Bd. lxxiii. s. 252, No. 87, taf. iv. fig. 4.
[2] *Chicago Med. Jour. and Examiner* (1884), p. 528.
[3] Reichert and Du Bois Reymond, *Arch. f. Anat.* (1872), s. 304.
[4] *Journal of Anat.* (1872), p. 56.

this kind in men have been recorded by Leichtenstern[1] and Hamy;[2] and in women by Rapin,[3] De Sinéty,[4] &c.

Abdominal mammæ in human beings are very rare. I know only of the following cases—

The most remarkable is Tarnier's.[5] He says, "I have myself seen a woman with four breasts, who died in the Maternity Hospital. Two breasts of the usual size occupied the normal position; while two others, as fully developed, were situated on the upper and lateral parts of the abdomen, nearly in the vertical line with the thoracic ones. At the necropsy I found abundance of glandular tissue in all four breasts, which also contained milk."

Bartholin[6] has seen a woman with a pair of supernumerary mammæ in the same situations, each the size of the normal male breast.

Bruce[7] has described and figured a redundant nipple in this situation in a man, and says he has seen several other instances of the kind.

In Mortillet's case, already alluded to, the patient was a young conscript with a pair of supernumerary mammæ in this situation nearly as perfect as the normal ones.

It seldom happens (12 out of 166 cases) that supernumerary mammary structures are met with *above* the normal glands. When this is the case, it is interesting to note that the redundant structures are always found *external* to the normal ones, as in polymastic animals. Cases of this kind will be cited in the section on axillary mammæ.

Probably all races of men are subject to these malformations; instances have been met with in nearly all European nations, and, in addition, in a Mongol, West Indian, Malayan, in a Mulattress from the Cape, a Moorish woman, and a Negress.

With regard to their occurrence in animals, Owen says:[8]— "In the Orang-utan (*Pithecus satyrus*), I have observed an accessory nipple on the left side, below the normal one, and of smaller size."

According to Sanson,[9] cows often have more than four teats,

[1] *Op. cit.*, s. 251 (No. 85), taf. iv. fig. 2.
[2] *Bull. de la Soc. d'Anthropologie*, t. 8 (1885), p. 229.
[3] *Rev. Méd. de la Suisse Romande* (1882), p. 472.
[4] *Gaz. Méd. de Paris* (1887), p. 317.
[5] Cazeaux, *Op. cit.* p. 86.
[6] *Epist. Med.*, cent. iv. No. 38, p. 218.
[7] *Journal of Anatomy*, vol. xiii. (1879), p. 446.
[8] *Comp. Anat.*, vol. iii. p. 780.
[9] *Bull. de la Soc. d'Anthropologie*, t. ix. (1886), p. 511.

the supernumerary ones being always placed behind the normal ones; whereas in sheep, which are also prone to this anomaly, the additional teats are always found in front of the normal ones.

Daubenton[1] has described a goat with double teats on each udder; and Sutton[2] has met with instances of the deformity in various monkeys, cows, and other animals.

It may be inferred, with tolerable certainty, that all animals having normally but a few mammæ, are liable occasionally to have additional ones developed.

The question has been raised whether polymastic women are more liable than others to beget more than a single child at a birth. Of seventy polymastic women in Leichtenstern's list, three had given birth to twins, or 4·3 per cent; this proportion is much above the average, which for Great Britain is only about 1 per cent.

In polymastia the normal pectoral pair of mammæ are invariably present in their proper position, and well developed.

It is very unusual to find these anomalies associated with other congenital malformations, as in cases of amazia.

Bryant,[3] however, has seen a girl, aged six, with a supernumerary nipple on the left side, below the normal one, in whom the vagina was absent, and she had a clitoris as large as a boy's penis.

Voltaire[4] also relates having seen at a fair a woman with a pair of redundant mammæ, "qui portait de plus au croupion une sorte d'excroissance converte de peau et de poils, la quelle ressemblait à une queue de vache."

It is alleged that in the beautiful Anne Boleyn, polymastism was associated with polydactylism.

Supernumerary mammæ are often hereditary. In seven out of ninety-two cases (7·6 per cent.) collected by Leichtenstern there was history of similar malformation in near relatives.

In Petrequin's case,[5] the father, his three sons and two daughters, each had a single supernumerary pectoral mamma.

Handyside[6] has seen two brothers, each with a supernumerary pair of pectoral nipples below the normal ones.

[1] Fourcroy's *Méd. eclairée*, t. v. tab. 12.
[2] *Internat. Jour. of Med. Sci.*, vol. xcvii. (1889), p. 247.
[3] *Diseases of the Breast* (1887), p. 9.
[4] *Dict. Philosophique*, art. "Monstres."
[5] *Gaz. Médicale*, av., 1837, p. 195.
[6] *Journal of Anatomy*, vol. vii. (1872), p. 56.

In a case related by Edwards,[1] a man had a single additional nipple, with areola below the right mamma, and his sister had a similar deformity of the left side. Edwards had the opportunity of examining both persons.

Bathurst Woodman[2] has recorded the case of a woman with a supernumerary nipple below the left breast, whose daughter had the like deformity.

Roberts' case has been already mentioned.

Other instances of hereditary polymastism have been recorded by Bartholinus,[3] Tiedemann,[4] and Scalzi.[5]

Anomalies of this kind are often overlooked for the want of knowing what to expect. Those who know *where to look* and *what to look for* are not likely to have much difficulty in making a diagnosis. In minor degrees of this deformity, instead of a redundant nipple, only a depression may be found (*athelia*). Hairs are never seen on normal nipples; but the supernumerary ones occasionally have them.[6] In many instances supernumerary mammary structures have been mistaken for moles, nævi, lipomata, and cold abscesses. Morbid growths in connection with the nipple sometimes stimulate supernumerary malformations. I lately saw a middle-aged married woman with a small *molluscum fibrosum* near the nipple, which it closely resembled.

I have already alluded to the resemblance between some cases of supernumerary mammæ and the condition resulting from chronic fistula, in connection with sebaceous and dermoid cysts that have undergone suppuration. Very little help is to be got from the metropolitan museums in this matter; altogether they contain but a single specimen! This *rara avis* is to be found in the museum of the London Hospital—a single supernumerary nipple from a man.

As a rule, supernumerary mammary structures, being small and rudimentary, hardly attract the notice even of those who bear them. Sometimes, however, especially in women during lactation, the overflow of milk from them causes considerable annoyance.

[1] *Phil. Med. News*, 1886, p. 264.

[2] *Obstet. Soc. Trans.* (London), vol. ix. (1867), p. 50.

[3] *Epist. Med.*, cent. iv., Hagæ Comitum, 1760; *Epist.* 38, p. 171.

[4] *Op. cit.*, s. 110.

[5] Puech, *Op. cit.* pp. 72 and 117.

[6] Bruce, *Op. cit.*

There can be no doubt as to the propriety of excising such redundant parts for those who desire to be relieved of the deformity, and the procedure is free from danger.

SECTION 5.

The subject of supernumerary mammary structures in the axilla and its vicinity is of such great practical importance, that I propose to devote a special section to its consideration.

Several anatomists have recognised the fact that, in females, a process of the mammary gland is not infrequently prolonged round the border of the pectoralis major muscle into the axilla.

According to Hennig,[1] the fully developed female mamma has normally a tricuspid form, two of the cusps projecting towards the axilla, an upper and a lower one, and the other towards the sternum.

It is the upper of these two axillary mammary extensions that so often extends right into the axilla.

Though commonest in the axillary region, similar glandular offshoots have been found to arise from other parts of the breast. The connection of these out-lying lobules with the main gland is often reduced to a narrow pedicle, and not infrequently they are completely sequestrated. In reference to this matter Sir Astley Cooper remarks:[2] "The margins of the breast do not form a regular disk, but the secreting structure often projects into the surrounding fibrous and adipose tissue, so as to produce radii from the nipple of very unequal lengths; hence a circular sweep of the knife cuts off many of its projections, spoils the breast for dissection, and, in surgical operations, leaves much of the disease unremoved."

Champneys[3] has related the following striking examples of this condition in lying-in women:—

1. On the third day after admission a mammary extension, two inches broad, was noticed in each axilla, to the apex of which it reached. These extensions joined the outer border of the mammary gland at a tangent; they felt nodular, and in all respects like the mamma itself.

[1] *Arch. f. Gyn.* Bd. ii. (1871), s. 331.
[2] *The Anatomy of the Breast*, London, 1840, p. 13.
[3] *Med. Chir. Trans.*, vol. lxix. (1886), p. 429.

2. On the sixth day after admission a mammary extension was felt on the inner wall of each axilla. These extensions were obviously connected with the breasts, and they felt just like them.

3. On the second day after admission there was noticed a nodular prolongation from the outer side of each mamma along the inner wall of the axilla, nearly to the apex.

No pore or nipple could be found in connection with any of the above extensions from which secretion could be expressed.

4 and 5. Charcot and Legendre[1] have, however, recorded two instances in which supernumerary nipples—in one case with and in the other without an areola—were met with in connection with axillary mammary extensions. Both the patients were women. In each there was but a single supernumerary nipple, which was situated just above and external to the normal one—in one case on the left side, and in the other on the right. In both these cases the connection between the supernumerary nipples and the mammary extensions was verified by *post-mortem* examination.

6. In Notta's[2] case there was a tumour the size of a walnut over the middle of the left anterior axillary border, which was connected with the breast by a narrow pedicle. On pressure milk escaped through a single small pore in the overlying skin. There was no sign of nipple or areola, and the other axilla was normal. The patient was a woman, aged twenty-six, who was suckling her fourth child. No escape of milk in the axilla had taken place during previous lactations. To account for this, Notta has made the feasible suggestion that on these occasions the secretion from the tumour was carried off by the normal nipple through the pedicle, which subsequently, for some reason or other, became occluded; when the accumulating secretion made its exit by the axilla. In order to determine the precise nature of this condition, Notta dissected the mammæ of a number of women. In one, aged twenty-six, who died in child-bed, he found an axillary mammary extension, which presented as—"Une sorte de cordon qui, suivant le bord externe du grand pectoral, remontait vers le milieu du deuxième espace intercostal."

7 and 8. Champneys[3] has seen two similar cases in lying-in women. In both there was supernumerary gland substance in each axilla, which discharged externally by a single pore at the middle of the anterior axillary borders.

We next come to a class of cases in which quite separate supernumerary mammæ have been found in these situations, *i.e.*, in positions which correspond to the 3rd pair of my diagram (fig. 1). I will cite four such instances.

1. In Shannon's case[4] (fig. 3) the patient was a woman, aged

[1] *Gaz. Méd. de Paris* (1859), p. 773.

[2] "Obs. de mam. surnumèraire," *Arch. de Tocologie*, 1882, p. 108.

[3] *Op. cit.*, pp. 430, 431.

[4] *Dublin Medical Journal*, vol. v. (1848), p. 266.

thirty-four, who came under observation soon after her sixth confinement, when it was noticed that she had a pair of supernumerary breasts just above and external to the normal ones (fig 3). Each of the redundant organs was the size of a large goose's egg. Curiously enough, the right supernumerary gland was furnished with two nipples, and the left with a single one; each nipple had its own well-developed areola, and during lactation milk flowed freely from them all, especially when the normal ones were being sucked. A mole-like body on the right supernumerary breast gave the appearance of a third nipple. The patient said she first noticed the supernumerary glands at about the time of puberty, and that they had always enlarged and given milk under the same conditions as the normal mammæ. She had never brought forth more than one child at a birth. The generative organs were normal. There was no history of any similar deformity among her relations.

2. Lee's patient[1] was a woman, aged thirty-five, in whom a pair of supernumerary mammæ were noticed shortly after her premature delivery of a still-born child. The redundant glands were situated just above and external to the normal ones; each had a single, small, flat nipple which yielded milk. She first noticed the deformity shortly after her first confinement ten years previously. She subsequently had several single children; and at thirty, she had twins. The generative organs were normal.

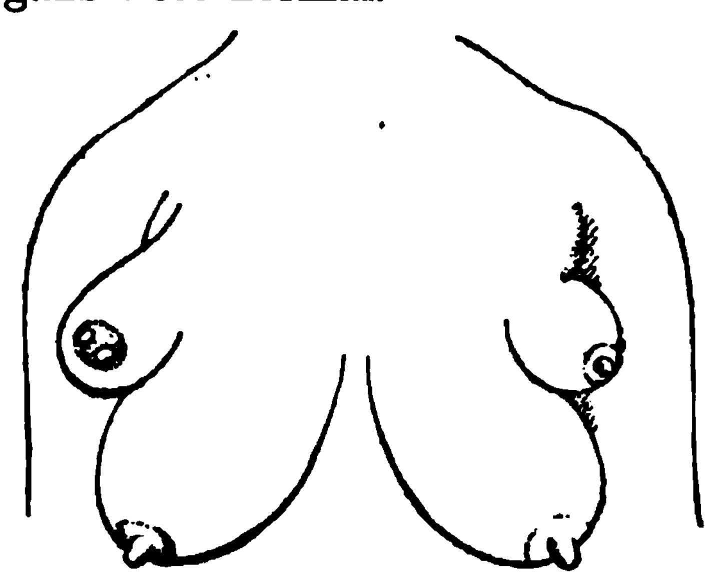

FIG. 3.

3. In Gardiner's case[2] the patient was a mulattress from the Cape, aged twenty-nine, healthy and well developed, except that she had a pair of supernumerary mammæ a little above and external to the normal ones. The redundant mammæ were smaller than the normal ones—about the size of those of a girl at puberty. After child-birth these glands enlarged, and gave milk.

4. Champneys[3] has observed in a lying-in woman a rudimentary nipple in the like situation just above the right breast. This woman had also an extra pectoral pair of nipples below and internal to the normal ones.

[1] *Med. Chir. Trans.*, vol. xxi. p. 266.

[2] Cited by Percy in his "Mém. sur les femmes multimammæ," *Journal de Méd, &c., de Corvisart.*, ann. xiii. t. ix. p. 383.

[3] *Op. cit.*, p. 434.

Several instances are on record of supernumerary mammary structures in a position above and external to that described in the foregoing cases, yet not in the axilla, but over the middle of its anterior border corresponding to the 2nd pair of my diagram (fig. 1). I can cite two cases of this kind:—

1. Quinquad's[1] patient was a woman, aged twenty-four, who, in addition to a large pair of normal mammæ, had another smaller pair situated above them, over the middle of each anterior axillary border. Each was the size of a small orange, and was furnished with well-formed nipple and areola. During lactation these glands gave milk. She had suffered from right internal strabismus since the age of two. There was no history of any malformations among her relatives. The areolæ of the normal mammæ were very large. Directly I saw her photograph this particular recalled to mind Cuvier's celebrated drawing of the Hottentot Venus,[2] whose areolæ were over four inches in diameter.

2. Bruce[3] has seen a man with a pair of rudimentary supernumerary nipples in the like position, who had also an extra nipple on the left side below the normal one.

The connection between pectoral and axillary mammæ is admirably illustrated by the three following rare cases of multiple mammæ:—

1. Fitzgibbon's[4] patient was a man, aged twenty-four, a native of Jamaica, who had four supernumerary mammæ: a well-formed pair below, and internal to the normal ones; and another rudimentary pair just above and slightly external to the normal ones.

2. In Mortillet's[5] case, two pairs of supernumerary mammæ were also present, but both were situated below and internal to the normal ones. The lowest pair was placed on the upper part of the abdominal wall, in the position of the seventh pair of my diagram (fig. 1); the other pair was situated between the foregoing and the normal pair, probably in the position of the fifth pair of my diagram, but as to this the description is not very precise. The patient was a healthy young conscript, and there was no history of any hereditary malformation in his family. The supernumerary mammæ were only a little less perfect than the normal ones. The lowest pair was the smallest.

3. Neugebauer's[6] case is remarkable for the large number of

[1] "Femme tétramaze," *Revue photographique des hôpitaux*, 1870, p. 16.

[2] "Femme de race boschismanne," *Hist. nat. des mammifères*, St Hilaire et Cuvier, t. i. (1824), p. 1.

[3] *Op. cit.*, p. 425.

[4] *Dublin Quarterly Journal of Medical Science*, vol. xxix. (1860), p. 109.

[5] *Bull. de la Soc. d'Anthropologie*, t. vi. (1883), p. 458.

[6] *Cent. f. Gynäk.*, 1886, p. 729.

supernumerary structures present, viz., eight, the largest number yet seen in any human being. This anomaly was met with in the person of a single woman of Warsaw, a domestic servant, who was admitted into the lying-in hospital for her second confinement. Her normal mammæ were large and well formed, and during lactation they gave an abundant supply of milk. Soon after her confinement, when suckling, she noticed an uncomfortable wetness in each axilla. On examination as to its cause, a supernumerary nipple without areola was found in each axilla, from which milk flowed freely when the child sucked either of the normal breasts. At the same time two other pairs of nipples, each with its own areola, were found above the normal ones. The upper pair was situated over the middle of each anterior axillary border; and the lower pair, just above the periphery of each bosom, and slightly external to the normal nipples. Shortly afterwards, on raising the pendent mammæ, two other unsymmetrical redundant nipples were found below and internal to the normal ones: that on the right side was immediately below the bosom, that on the left was some inches *lower down*. Neugebauer has spoken of these two unsymmetrical nipples as a *pair;* but it is quite clear to me that this is a mistake: the upper one evidently represents the right nipple of the fifth pair of my diagram, and the lower one the left nipple of my sixth pair (fig. 1). On pressure, milk escaped from all these redundant nipples. It is a curious fact that after her first confinement—seven years previously—she never noticed any abnormality about the chest, other than the presence there of several brown spots, which she took for moles. The patient was exhibited at a meeting of the Warsaw Medical Society. A woodcut, from a photograph, which accompanies the record of this case, makes it very complete.

I have found on record numerous cases of so-called axillary mammæ; but when one comes to examine these cases critically only three or four can be definitely accepted as such; most of the others are of the nature of axillary mammary extensions, and several of them were connected with the corresponding normal breast by a pedicle. I have not met with a single case of the kind in a male.

In animals axillary mammæ are rare, but they occur in the *Pteropi* (fruit bats) and in the flying lemur (*Galeopithecus*).

Of Leichtenstern's 105 cases of supernumerary mammæ, five were in the axilla (4·7 per cent.)

In a case observed and figured by this author,[1] there was a nipple the size of a split pea, without areola, at the top of the left axilla; and connected with it was a mass of gland substance the size of a walnut. The patient was a woman recently delivered of her first

[1] *Arch. f. Path. Anat.*, &c., Bd. lxiii. p. 245, No. 38, taf. iv. fig. 1.

child. When suckling, milk escaped from this nipple, as well as from another supernumerary nipple just below and internal to the left breast, though no gland substance could be felt beneath it.

A similar case has been recorded by D'Outrepont.[1] The patient was a pregnant woman with a tumour the size of a hen's egg in the left axilla, connected with which was a nipple, whence colostrum escaped.

Perreymond [2] has related the case of a woman, aged twenty-seven, who shortly after her second confinement noticed a tumour the size of a pigeon's egg in the right axilla. It was movable, and not connected with the breast. Over it was a small nipple surrounded by an areola. On pressure milk escaped. The tumour was first noticed about the time of puberty at the age of fourteen. At her first confinement it was taken for an abscess. Six weeks after delivery the secretion ceased, and the tumour diminished in size.

These three cases and Neugebauer's are the only instances known to me of axillary nipple.

Champneys [3] has related the case of a lying-in woman with a supernumerary gland in each axilla the size of a nutmeg, connected with the normal gland by a narrow pedicle. On pressure, milk escaped from each axillary swelling through a small pore in the overlying skin.

Martin,[4] Siebold,[5] Champion,[6] Harris,[7] Dixon,[8] and Moore,[9] have each of them seen a lying-in woman with a tumour the size of a hen's egg in both axillæ, whence milk exuded on pressure through several small pores in the overlying skin. No nipple was present in either of these cases; nor is mention made of any connection between the axillary tumours and the normal mammæ.

In a case seen by Cameron,[10] a woman aged thirty-three, in her sixth lactation, had a tumour the size of a hen's egg in the left axilla, from which milk escaped on pressure through a single small pore. She first noticed the swelling after having over-exerted herself in extinguishing a fire when she was pregnant with her sixth child. In all her previous confinements she was free from any axillary trouble. It seems probable here, as in Notta's case, that the tumour was formerly connected with the normal gland by a pedicle, which carried off its secretion *per vias naturales*.

Cohn [11] has recorded a precisely similar case, also on the left side.

[1] *Neue Zeit. f. Geburtsk*, &c., Hersang von Busch, &c., Bd. ix. (1840), S. 40.
[2] *L'Union Méd.*, 1874, t. 18, p. 864.
[3] *Op. cit.*, p. 423.
[4] *Annal. d'occulist et de gynécol*, t. i. liv. 8.
[5] *Med. Ztg. v. e. Verein f. Heilk.*, in Pr., 1838, No. 6.
[6] *Dict. des Sci. Méd.*, t. xxx. p. 377.
[7] *Medical Times and Gaz.*, vol. i., 1861, p. 397.
[8] *Lancet*, vol ii., 1843, p. 844.
[9] *Lancet*, 1838, p. 786.
[10] *Journal of Anatomy*, vol. xiii. (1879), p. 149.
[11] *Berlin Klin. Wochenschrift*, 1885, s. 291.

Matthews Duncan[1] has published an account of a woman, aged twenty-six, who, in the ninth month of her pregnancy, complained of constant wetness in the right axilla. Four days after her confinement a tumour the size of a walnut was found in this situation, which, on pressure, emitted milk through a single small pore in the overlying skin. The tumour had no obvious connection with the normal mamma.

Turney[2] and Hare[3] have met with precisely similar conditions in women, also on the right side.

In the cases of Harris and Hare milk cysts formed in the axilla.

SECTION 6.

Very little has hitherto been recorded as to the development of neoplasms from supernumerary mammary structures.

Having made this subject the object of special investigations during many years, I have arrived at the following results:—

Of fifty cases of *Fibro-adenoma* of the mammary region consecutively under observation, I found that seven (14 per cent.) had originated in supernumerary mammary structures, quite outside the normal mammæ.

I append brief abstracts of these cases:[4]—

1. A well-formed, healthy, single woman, aged thirty-six, a cook had a hard, circumscribed, ovoid tumour, the size of a bantam's egg just above and external to the right bosom. There was no connection between the tumour and the mammary gland; and it was free from adhesions with the adjacent structures. The nipple and axillary lymph glands were normal. The patient said she first noticed a small lump in the site of the present tumour six months previously. There was no history of previous injury or disease of the part. Her mother died of cancer of the left breast. The catamenia had always been regular. During the last few years she had been subject to bilious dyspeptic attacks; but otherwise her previous health had been very good.

The tumour was dissected out. It was encapsuled and solid, and unconnected with the mamma. It presented to the naked eye the ordinary appearance of fibro-adenoma.

On *microscopic examination* acini and ducts were seen embedded in fibro-fatty tissue. The acini were arranged in grape-like clusters, as in the normal mamma; but most of their cells were in granular de-

[1] *Obstetrical Journal*, vol. i. (1873), p. 516.

[2] *Phil. Med. News*, 1886, p. 264.

[3] *Lancet*, vol. ii. (1860), p. 405.

[4] For further details, vide *Middlesex Hospital Surgical Reports* by the author, for the years 1882–1889.

generation, and in some places small cysts had formed. The ducts were seldom excavated, and their cells were also in granular degeneration.

2. A well-nourished single woman, aged thirty-eight, with a hard, movable, circumscribed tumour, the size of a large walnut, just above the right bosom. No enlargements of the adjacent lymph glands. Slight congenital retraction of both nipples. The tumour was first noticed three weeks previously. No injury or known cause for it. Catamenia always regular. Previous health good. Her father died, aged sixty-nine, of cancer of the stomach; and she has lost a sister with cancer of the breast.

The tumour was dissected out. It proved to be a typical, solid, fibro-adenoma, unconnected with the breast.

3. A pale, fair woman, aged twenty-six, with two small, hard, nodular tumours above the left bosom, and entirely unconnected with the gland. The nipple and adjacent lymph glands normal. The tumours of three months' duration. The patient had been twice married. By her first husband she had one child and two miscarriages. Her previous health had been good. She lost her mother of "internal tumour."

The tumours were dissected out. Each had the appearance of ordinary fibro-adenoma. On *microscopic examination* glandular acini in the resting stage were seen, surrounded by nucleated fibrous tissue, which contained a few spindle cells.

4. A healthy-looking woman, aged forty-three, who had on the axillary side of the left breast, and unconnected with it, a smooth, hard, movable tumour, the size of a walnut. No enlargement of the adjacent lymph glands. It was first noticed two months previously. Both nipples were congenitally retracted. Catamenia regular. The tumour was excised—a typical, solid, encapsuled fibro-adenoma.

5. A healthy woman, aged forty, with a hard, racemose tumour, the size of a walnut, over the edge of the sternum, on the left side, quite outside the mamma. It was first noticed three years previously. The patient had married at twenty-one, and had cohabited with her husband ever since, but she had never been pregnant. On examination of the tumour after removal, it was found to be an encapsuled, loculated fibro-adenoma. The loculi were full of papillary ingrowths. On *microscopic examination* fibro-adenoma—the intralocular growths consisted of fibrous processes lined with cubical epithelium.

6. A single woman, aged twenty-seven, a dressmaker, with a circumscribed tumour, the size of a hazel nut, over the edge of the sternum on the right side, and unconnected with the mamma. It was first noticed nine months previously. The tumour was dissected out; and it proved to be a solid ordinary fibro-adenoma.

7. A single woman, aged thirty-two, who had a firm, nodular tumour, the size of a walnut, just below and quite outside the left bosom. It was first noticed two years previously. Her sister had a similar mammary tumour. It was dissected out, and proved to be an ordinary solid encapsuled fibro-adenoma, unconnected with the mamma.

Very few instances of this kind have hitherto been described. Cameron[1] has related two such.

The first was a single woman, aged thirty, who, five years previously, first noticed a lump the size of a walnut in her right axilla.

On examination, there was found in this situation an ovoid, elastic tumour, the size of a large cricket ball. It had been rather painful for the last two years.

The tumour was excised. There was no difficulty in the operation, because it was encapsuled, and readily shelled out. On section, after removal, it looked like a fibro-lipoma; but on *microscopic examination* it proved to be an ordinary fibro-adenoma.

In the second case the patient was also a single woman, aged thirty-three. She had a tumour, "the size of the fist, in the axilla." It had not increased in size since puberty. No operation was done.

In the Museum of University College Hospital I have found an interesting specimen of this disease, which is thus described in the Catalogue[2]:—"A large tumour removed from the mammary region. It is rounded in form, and measures 5 inches in its long diameter. Its surface is slightly lobulated, and it is enclosed in a loose capsule of areolar tissue. The section shows the tumour to be composed of closely packed lobules, bound together by a moderately abundant fibrous stroma. The resemblance to a section of the pancreas is almost perfect. There is one cyst, about half an inch in diameter, seen in the section. It has some fine papillary intra-cystic growths projecting into it. The tumour was removed by Quain from a lady, aged twenty-six, the mother of several children. It was first noticed eighteen months before operation; and during the last six months it had increased continuously. At the time of the operation the lady was six months pregnant. The tumour was on the left side, and did not implicate the mamma, which was quite free from it. After removal it weighed four pounds. On *microscopic examination* the tumour was seen to be composed of a structure closely resembling that of the normal mamma. Groups of acini were present, lined with abundant epithelium, which in some places quite filled them up. Here and there small ducts were seen which communicated with the acini; but no large ducts were seen which received the smaller ones. The inter-acinous tissue was very abundant, and consisted of mature fibrous tissue. No fat was found in any part of the specimen."

In dissecting a breast Eve[3] found a firm nodule, about the size of a hazel nut, lying near the axillary border of the right gland, but completely detached from it. On microscopic examination it consisted of large duct tubes lined with short columnar epithelium, which were in places enormously dilated. There were also present other smaller ducts, which ended in acini. These structures were embedded in fibrous tissue. The tumour was in almost all respects just like an accessory mammary glandule. The patient was a woman, aged fifty-

[1] *Journal of Anatomy*, vol. xiii., 1879, p. 150.
[2] Vol. ii., 1887, p. 445, No. 1960.
[3] *Brit. Med. Journal*, vol. i., 1883, p. 298.

nine, who died of bronchitis, after removal of epulis of the lower jaw. In addition to this tumour she had at the upper and inner part of each breast a small ordinary adenoma.

Sir Spencer Wells[1] refers to other cases of the kind in his Morton Lecture.

With regard to the development of *Cancer* in supernumerary mammary structures, I have the following observations to record.

Of 132 cases of cancer of the mammary region in women, consecutively under observation, I found that 13 (9·8 per cent.), had originated in supernumerary mammary structures, quite outside the normal mammæ.

I append brief abstracts of these cases.[2]

1. Single, aged fifty. Six months previously she first notice a lump in the sternal side of left breast. On examination, a hard nodular cancerous tumour, the size of a walnut, in this situation, quite outside the mamma. The overlying skin adherent; no obvious affection of the adjacent lymph glands. Amputation of the breast, and removal of the tumour with it. No history of tumour or cancer in the family.

2. Single, aged seventy-one. Seven years previously a hard nodule first noticed at the upper part of the chest, some distance above the left bosom. Six years ago the breast amputated, and the tumour removed. Recurrence at the primary seat five years later. No history of tumour or cancer.

3. Single, aged twenty-nine. Two years previously, first noticed a hard lump, the size of a pea, above the left bosom, and unconnected with the gland. In the course of four months it increased to the size of a marble. It was then excised; but the breast was left. Recurrence at the primary seat six weeks later; this again excised. Nine months later further recurrence in the same locality. On examination, a hard lump, the size of a brazil nut, above the left breast, over the 2nd intercostal space. The breast still quite free. Several small hard glands above and below clavicle. Just below the tumour, are the scars of the former operations. Axillary glands free. The recurrent disease again freely excised. She was convalescent twenty-four days later; and I have not seen her since. No history of cancer or tumour in the family.

4. Single, aged forty-five. Quite below the left breast, on its axillary side, is a hard, fixed, nodular tumour, with the overlying skin infiltrated and ulcerated. The disease was first noticed a year previously; when it presented as a lump the size of a hazel nut. The axillary glands enlarged. No history of cancer or tumour. Breast amputated; the tumour and axillary glands removed.

5. Aged fifty-four, married at forty-two, never pregnant. At lower

[1] Churchill, 1888, p. 22.

[2] For further details, vide *Middlesex Hospital Surgical Reports* by the author, for the years 1882–1889.

and axillary side of right breast, quite outside the gland, is a hard, knobby, rounded tumour, the size of a small orange. Nipple normal. Overlying skin adherent. Axillary glands enlarged. The tumour was first noticed one year previously. No history of cancer or tumour. Amputation of breast; removal of tumour and axillary glands.

6. Single, aged forty-six. Above the left breast, and on its inner side, is a hard, nodular tumour, the size of a bantam's egg, quite outside the mamma. Nipple normal. Overlying skin adherent. Axillary glands slightly enlarged. First noticed four months previously. Amputation of breast with the tumour, and removal of axillary glands. No family history of cancer or tumour.

7. Married, mother of three children, age fifty-one. Above the right bosom, over the middle of the anterior axillary fold, is a hard, nodular tumour, the size of a hen's egg, quite outside the mamma. The overlying skin adherent; the axillary lymph glands enlarged. Duration of tumour eighteen months. Removal of breast, tumour, and axillary glands. No family history of tumour or cancer.

8. Married, four children and one miscarriage, age sixty-seven. Three years ago first noticed a hard tumour at the sternal side of left bosom, unconnected with the gland. Three months later it was excised; but the breast was not removed. Recurrence set in, at the primary seat six weeks ago. On examination over the edge of sternum, on the left side, quite outside the mamma, is a tumour the size of a walnut, in the old scar. Nipple normal. No enlargement of axillary glands. Amputation of breast and removal of tumour.

9. Single, aged sixty-four. Over the edge of the sternum, on the left side, is a hard, rounded tumour, the size of an orange, firmly adherent to the adjacent structures. The lymph glands of left axilla enlarged. The patient says the disease began as a lump, quite outside the breast, eighteen months ago. No family history of cancer or tumour. No operation.

10. Single, age forty-nine. Four and a half years ago a hard lump first noticed quite outside the left bosom, near the axilla. A fortnight later, breast amputated and tumour removed. Recurrence at primary seat and in axilla two years later. Her sister died of cancer of the breast.

11. Married, six children, aged forty-seven. Above the left breast, over the edge of the sternum, is a hard tumour the size of a walnut quite outside the bosom. It is adherent to the adjacent parts. Nipple retracted; axillary glands full. The patient says she first noticed a lump in site of present disease, outside the breast, two years ago. Amputation of breast and removal of tumour; axilla not touched. No family history of cancer or tumour.

12. Single, age sixty-two. Over the right edge of sternum, opposite the middle of the breast, but unconnected with it, is a hard tumour the size of an orange. The overlying skin is infiltrated; and the axillary glands are enlarged. The disease was first noticed two years ago as a tumour the size of a hazel nut, over the edge of the sternum. Congenital contraction of the nipple. No family history of cancer or tumour. Breast amputated, tumour removed, and axilla cleared.

13. Single, age sixty-nine. Pale and weak. Just beyond the periphery of the axillary part of the right bosom is a hard, nodular tumour, the size of a small orange. The overlying skin adherent; axillary lymph glands enlarged. Duration five years. Breast amputated, tumour removed and axilla cleared.

Among these 132 cases there were a few others, in which it seemed almost certain that the disease originated quite outside the mamma, but as I could not be quite sure of it I have omitted them.

With regard to the literature of the subject—

Foerster[1] has cited a case by Busch, in which cancer developed in a supernumerary mamma in the neighbourhood of the axilla. The breast was amputated and the axillary cancer was dissected out. On examination after removal, the mammary gland was found to be unconnected with the axillary tumour, and free from the disease. In connection with the cancerous tumour, some of the supernumerary axillary mamma still remained uninvaded by the disease. On *microscopic examination* this was seen to consist of glandular tissue, just like that of the normal mamma.

Gluck[2] has recorded an interesting case of the kind. The patient was a woman who for twenty-eight years had been affected with a hard, freely movable tumour, quite above the mamma. This swelling, after remaining stationary for many years, subsequently increased much, and presented all the appearances of cancer. The tumour was then excised, and it was evidently cancerous, as it recurred two years later. Here we have an adenoma developed from a supernumerary mammary structure; and from the adenoma cancer subsequently originated.

Billroth[3] mentions having seen acinous cancer develop in a breast with two nipples.

In the Hunterian Museum[4] is half a cancerous tumour, removed from the axilla of a lady, aged thirty-five. The breast and the skin over it were normal. It was easily detached. *Microscopical examination* revealed alveolar cancer. This is evidently a case of the kind we have been considering.

[1] *Die Missbild. der Mensch*, 1861, s. 49.
[2] *Berlin klin. Wochenshrift*, 1885, s. 292.
[3] "Die Krankheiten der Brustdrüsen," *Deutsche Chirurgie*, Lief. 41, 1880, s. 10.
[4] *Path. Catalogue*, vol. iv. p. 292, No. 4811A.

CONTRIBUTIONS TO THE PHYSIOLOGY AND PATHOLOGY OF THE BLOOD.[1] By ROBERT MUIR, M.A., M.D., *Assistant to the Professor of Pathology, Edinburgh University.* PART I. (PLATE VI.)

I PROPOSE to give an account of some of the histological characters of the corpuscular elements of the blood, including the blood-plates, of the alterations which those elements undergo in pathological conditions, and of some experiments on the changes produced in the blood and blood-forming organs by hæmorrhage.

The present paper is occupied chiefly with a description of the blood-plates, and with a review of the literature of the subject. The methods employed have also been shortly described.

METHODS.

The methods which I have chiefly employed in the examination of the blood and of the cell-elements of the blood-glands are the following, viz.:—Examination of the fresh blood or of the expressed juice of the glands, without any reagent whatever, examination in various preserving fluids, and by means of specimens prepared by drying and afterwards stained. All these methods ought to be employed in concert, so that the results obtained by one method may be controlled by the others. In the case of the blood, enumerations of the various elements have also been made.

The first of these methods requires no explanation. The examination ought to be made with as little delay as possible, and undue pressure by the cover-glass must be avoided, as it tends to increase the diameter of spherical corpuscles. Measurements of the size of the various cell-elements are only trustworthy when they are made in the fresh condition. In the case of the bone marrow dissociation is generally necessary, and

[1] Being an abridgment of the chief part of a Thesis, which was presented to the Faculty of Medicine of Edinburgh University for the degree of M.D., and for which the author was awarded a Gold Medal on August 1, 1890.

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can be rapidly effected by laying a fragment on a slide and tapping it perpendicularly with a glass rod. I have made use of various preserving fluids, some of which are tinted, some are not. Hayem's solution (sodium chloride 1, sodium sulphate 5, mercury perchloride 0·5, distilled water 200), and a 1 per cent. solution of osmic acid are suitable for examination of the blood-plates. Bizzozero's methyl-violet salt solution (·6 per cent. solution of sodium chloride, tinted with methyl-violet 1 : 5000, or with gentian-violet 1 : 3000), Afanassiew's peptone salt solution (·6 per cent. sodium chloride, and ·6 per cent. dried peptone in distilled water, tinted with methyl-violet, and with a little carbolic acid or corrosive sublimate added to prevent decomposition), and a solution of sodium sulphate, sp. gr. 1022, coloured with methyl-violet, are useful, as they tint the blood-plates and colourless corpuscles, leaving the red corpuscles unstained. In my enumerations I have chiefly employed the last-mentioned solution. Arnold employs for the examination of the bone marrow a methyl-green salt solution, to which a few drops of a ·25 per cent. solution of chloride of gold have been added, and Löwit recommends a 1 per cent. solution of sodium chloride, with which is mixed a little of Flemming's solution (chromic acid ·25, osmic acid ·1, glacial acetic acid ·1, distilled water 100). In the case of the blood, a drop of the fluid is laid on the cleansed skin, and the prick made through the drop, so that the blood at once flows into it, and is mixed with it; in the case of the blood glands, a small piece of tissue is dissociated in a large drop of fluid placed on a slide. For this latter purpose I have chiefly employed Bizzozero's methyl-violet solution.

Dried films, prepared according to Ehrlich's method, are the most suited for permanent preparations. A drop of blood of suitable size is allowed to spread itself out into a thin film between two cover-glasses, which must be scrupulously clean; the two cover-glasses are separated by sliding the one on the other, and the films are dried by a rapid to-and-fro motion in the air. Ehrlich recommends that the films afterwards be kept for some hours on a copper plate, at a temperature of 120° C., in order that the hæmoglobin may be fixed. For most purposes, however, this is unnecessary, especially if the films are rapidly stained with alcoholic solutions. The hæmoglobin

is less liable to be dissolved out if the films are kept for a week or so. Dried films may also be made of blood mixed with the 1 per cent. solution of osmic acid, in the above-mentioned manner. I have found the following stains to be the best amongst a great number which I have tried:—A saturated solution of methyl-blue in absolute alcohol, stain for about thirty seconds; this stains the nuclei of a bright blue colour, and is perhaps the most generally useful stain. Fuchsin, 5 per cent. in absolute alcohol, stain for about thirty seconds; it stains all the elements well, including the blood-plates. A beautiful contrast stain is obtained by using the methyl-blue first, washing and drying, and thereafter staining with fuchsin for fifteen seconds. The nuclei are blue, the red corpuscles crimson, and the blood-plates of a slightly violet tint. Eosin, in weak alcoholic solution 1 : 1000, can also be used as a contrast stain, but the blue colour is not so well retained as with the fuchsin. Aurantia, in strong alcoholic solution, stains red corpuscles of a bright yellow colour, but does not distinguish nuclei; stain for about twenty seconds. Methyl-green, in saturated watery solution, and saffranin, in alcoholic solution, are beautiful nuclear stains; stain for about an hour, after having fixed the films by floating for half an hour in Flemming's or Hayem's solution. Films fixed thus in Hayem's solution, and stained for twenty minutes in a watery solution of gentian-violet 1 : 800, generally show the blood-plates with great distinctness. In all cases, after being stained the films are washed in water, allowed to dry, and mounted in Canada balsam. More recently I have hardened the blood by dropping it into Flemming's strong solution, allowing it to remain for a day, and then completing the hardening in alcohol. It is then embedded in paraffin, and cut with the rocking microtome. The sections are stained on the slide, with hæmatoxylin, &c. This method shows the nuclear structure well, and is useful for comparison with the film preparations.

In enumerating the various elements, I have employed the Thoma-Zeiss hæmacytometer, which is especially suitable for counting the blood-plates. In order that this may be done satisfactorily, the drop of blood should appear at once after the prick in the skin is made, and should be of spherical form. It should be sucked up at once to the proper height in the tube,

and the fluid sucked after it as quickly as possible. The blood can thus be mixed with the preserving fluid within a few seconds after appearing on the skin. To any one acquainted with the stickiness of the blood-plates the objection at once presents itself that some blood-plates may adhere to the tube and thus escape enumeration. This I at once saw, and I thought it might be overcome by the following method, (which I afterwards found had been suggested by Laker some time before). This method is to mix the blood with osmic acid solution laid on the skin, to place the mixture in the cell of the hæmacytometer, and to count the relative proportion of blood-plates to red corpuscles; then, by obtaining the absolute number of red corpuscles by a separate enumeration, to calculate the number of blood-plates. On making trial of it, however, I found it so difficult to regulate the suitable proportion of blood to osmic acid solution, and to obtain a uniform mixture, that it was quite inapplicable for clinical purposes. After a little practice, and by the employment of sufficient care, one can obtain by the former method very good results, though only approximately accurate. In making the enumeration it is important to remember that the blood-plates take longer to sink to the bottom of the cell than the red corpuscles, and hence it is advisable to count them after the red and white corpuscles. I generally count the number in the whole ruled area, consisting of 400 small squares (equal to 100 squares in the Gowers' cell).[1]

THE BLOOD-PLATES.

Historical.—Though the blood-plates were first brought into prominent notice by the papers of Hayem, yet their presence in the blood had been observed at a much earlier date, and the theory had even been advanced that they were the progenitors of the red corpuscles. Interest in the subject was much increased by the publication of Bizzozero's work, and since that time they have been the subject of much investigation. The discussion within recent years has been principally regarding their supposed relationship to the red corpuscles, the part

[1] For further details on methods see Ehrlich, *Archiv f. Anat. u. Phys.* (Phys. Abtheil.), 1879, pp. 166, 571, and *Zeitsch. f. Klin. Med.*, vol. i. p. 553; Löwit, *Die Bildung rothen und weissen Blutkörperchen*, p. 6; Müller, "Zur Frage der Blutbildung," *Sitzungsber. d. k. Akad. d. Wis. in Wien*, vol. xcviii., June 1889.

they play in coagulation and thrombosis, and their existence in normal circulating blood, Bizzozero's views on the last subject being opposed chiefly by Löwit and by members of the Dorpat school.

Donné,[1] in a paper (1842) on the origin of the red corpuscles, mentions another element in the blood besides the red and the white corpuscles. He describes small bodies, 3 μ in diameter, which unite in threes and fours, and, becoming coated with an albuminous layer, form white corpuscles. He calls them "globulins du chyle," because they resemble the globules found in the chyle, and it is accordingly doubtful whether the bodies in question are really blood-plates or fat globules. There is little doubt, however, regarding the identity of bodies described by Zimmermann as "Elementarkörperchen" or "Elementarbläschen." His first paper, published in Rust's *Magaz. f. d. Gesam. Heilk.*, in 1846, I have been unable to see, but, owing to a criticism by Virchow,[2] his views were repeated in *Virchow's Archiv.*[3] The small bodies described by him are 2–3 μ in diameter, round, oval, or rod-shaped, and some of them are colourless, others tinted of a yellow colour. Those latter, he says, are the older forms, and become red corpuscles. He found them present when the blood had been mixed with neutral salt solution, and believed that they were present in circulating blood and not formed by precipitation on its being shed. The various reactions of those bodies agree with those of the blood-plates. Schultze, in critising Zimmermann's theory, considers that the colourless forms are identical with his "Körnchenbildungen," (v. sub), whilst the coloured forms are derived from the red corpuscles by the method employed. Kölliker[4] describes in the blood, "Elementarkörnchen fettiger Natur," globules of oil covered with an albuminous layer. These are evidently quite another structure, though it is remarkable that Kölliker so often met with them. The small spherical masses of germinal matter described by Beale,[5] some of which, according to him, become red and white corpuscles, are of uncertain nature. Their identity with blood-plates is very doubtful. On the other hand, the heaps of colourless elements which Schultze[6] observed in normal blood, and which he called "Körnchenbildungen," are undoubtedly collections of altered blood-plates. He gives an accurate account of their shape, size, general appearance, and behaviour to reagents, but is rather inclined to look upon them as destruction-products than as separate elements. He notices that during coagulation the fibrin filaments often shoot out from them, and mentions that he found them especially numerous in

[1] Donné, "De l'origine des Globules du Sang," *Compt. Rend.*, 1842, p. 366.

[2] *Cellular Pathology*, p. 224.

[3] Zimmermann, "Zur Blutkörperchenfrage," *Virchow's Archiv*, vol. xviii. p. 221.

[4] Kölliker, *Handbuch der Gewebelehre*, 3rd ed., p. 620.

[5] Beale, "Trans. Mic. Soc." in *Quart. Jour. of Mic. Sci.*, 1864.

[6] Schultze, *Archiv f. Mikroskop. Anat.*, vol. i. p. 36, 1865.

the blood of an anæmic woman. A little later Bettelheim [1] describes small rod-shaped corpuscles in the spaces between the red corpuscles, but it is impossible to speak as to their exact nature.

In 1872 Riess [2] wrote a paper describing heaps of granular bodies found in great numbers in the blood in certain conditions, which, from his drawings and description, I have no doubt are collections of blood-plates fused together. He believed them to be formed by the breaking down of white corpuscles, and called them therefore "Zerfallskörperchen." In accordance with this view, he found them most numerous in conditions where the vitality of the corpuscles is impaired, *e.g.*, after fevers, in the cachexiæ, &c. He looked upon them as practically pathological products, and thought that in some conditions they might form plugs in the small blood-vessels. About the same time, Lostorfer [3] described somewhat similar bodies as characteristic of the blood of syphilitic patients, Nedswetzki [4] described small round cells which apply themselves like knots to the fibrin network during coagulation, and Laptschinsky,[5] in a paper on alterations of the blood in disease, noted the occurrence of granular masses which he believed to be derived from the breaking down of white corpuscles.

It was in the condition of granule masses that these bodies were known to most observers, and their real nature was almost entirely overlooked. In 1874, Osler [6] gave a description of these masses, and the changes which they underwent in certain conditions. He recognised that it was quite impossible for such masses to pass through the capillaries, and that they were really composed of small corpuscular elements. He found, moreover, that in the vessels of the subcutaneous tissue of the new-born rat these elements were quite separate from one another, and had no tendency to adhere together. He was the first, so far as I know, to recognise that their change of form, &c., was due to the shedding of the blood. Ranvier,[7] in his work on histology, describes as normal elements of the blood little angular bodies ("granulations libres") resembling the white corpuscles in appearance, but differing from them in their physico-chemical reactions. Those, which are evidently blood-plates, he considered to be pre-formed pieces of fibrin which act as centres of coagulation, the fibrin filaments always shooting out from them.

It is to Hayem,[8] however, that we are indebted for a complete description of these bodies and for placing them on a firm histological basis as distinct elements of the blood. His papers were communi-

[1] Bettelheim, *Centralb. f. d. Med. Wis.*, 1868, p. 345.

[2] Riess, "Zur pathologischen Anatomie des Blutes," *Archiv f. Anat. u. Phys.*, 1872, p. 237.

[3] Lostorfer, *Centralb. f. d. Med. Wis.*, 1872, p. 281.

[4] Nedswetzki, *Centralb. f. d. Med. Wis.*, 1873, p. 147.

[5] Laptschinsky, *Centralb. f. d. Med. Wis.*, 1874, p. 657.

[6] Osler, *Proc. Roy. Soc.*, 1874.

[7] Ranvier, *Traité technique d'histologie*, p. 218.

[8] Hayem, Papers in *Archives de Physiol.*, 1878, 1879.

cated towards the end of 1877, and published in the following year. The two facts which he endeavours specially to prove are, that they are the progenitors of the red corpuscles, and that they are the means by which coagulation is brought about. He calls them accordingly "hæmatoblasts" and describes them as small round biconcave discs tinted with hæmoglobin. The yellow colour is most marked in those of largest size, and is readily lost when the blood leaves the vessels. They are non-nucleated and probably consist of a stroma with contents. They become red corpuscles by acquiring more hæmoglobin and greater stability of constitution, and by increase in size. The average size of the hæmatoblasts which he gives is greater than that generally given, and the two properties which are weightiest in support of his theory, viz., their biconcavity and their containing hæmoglobin, are disputed by nearly all observers. In support of the theory that they are the active agents in coagulation he brings forward many important facts. Later, Hayem,[1] by prolonged staining with hæmatoxylin, revealed a small central body in the hæmatoblasts which he believed to be a nucleus. I think, however, with Afanassiew and Eberth, that it is merely a small granular body which takes the stain more deeply.

In 1879, Leube[2] reported a case of essential anæmia in which there was a great increase of "Körnchenbildungen" (Schultze), but without deciding definitely as to their nature, and about the same time Riess[3] repeated and amplified his former views that they are destruction-products of the white corpuscles. An increased number of leucocytes and a state of impaired nutrition are therefore the conditions which cause an increase in their number. He also mentions conditions in which both leucocytes and blood-plates are diminished in numbers. Criticisms of Hayem's theory came from Ehrlich[4] and Neumann.[5] The former holds that the hæmatoblasts are derived from the red corpuscles, which in certain conditions undergo a degeneration, with altered staining reactions, and thereafter break down; whilst the latter considers that the intermediate forms between the hæmatoblasts and red corpuscles are artificial products formed from the latter by the method employed. Pouchet[6] supports Hayem's theory that the hæmatoblasts are the progenitors of the red corpuscles. He believes, however, that they are not cells or their derivatives, but are formed in the plasma of the blood within the vessels, in a manner analogous to the formation of fibrin, by the union of albuminous and crystalline components, and afterwards increase in size. Norris[7] gives quite another explanation of Hayem's hæmatoblasts. His theory is that red corpuscles are produced from colourless discs formed in the lymph glands by their gradually assuming hæmoglobin. Those discs

[1] Hayem, *Archives de Physiol.*, 1883, p. 363.
[2] Leube, *Berl. Klin. Woch.*, 1879 p. 653.
[3] Riess, *Berl. Klin. Woch.*, 1879, p. 696.
[4] Ehrlich, *Berl. Klin. Woch.*, 1880, p. 405, and 1881, p. 43.
[5] Neumann, *Zeitsch. f. Klin. Med.*, vol. iii. p. 411.
[6] Pouchet, *Quart. Jour. of Mic. Sci.*, 1880. p. 331.
[7] Norris, *The Physiology and Pathology of the Blood*, p. 71.

which are just beginning to acquire hæmoglobin tend to break down on the blood being shed, and form the characteristic granule-heaps. They are therefore the destruction-products of the progenitors of the red corpuscles. I have seen nothing to support this theory.

In 1882, Bizzozero[1] published his well-known paper on a new element of the blood to which he gave the name of blood-plate (Blutplättchen). He does not hold, however, that this element has never been described before—on the contrary, he fully acknowledges the work of others—but simply lays claim to priority of observing it within the living vessels. The mesentery of a chloralised guinea-pig was stretched on a cork frame in a bath of normal salt solution, and its small vessels examined in this way under the microscope. He found, by this means, circulating with the other elements of the blood, small colourless discs, which were of definite shape, and had no tendency, in these conditions, to adhere to one another. To his experiments there is only one objection, viz., that the abnormal conditions—exposure to cold and mechanical influence—to which the vessel walls were subjected, might induce destructive changes in some of the other elements, especially in the leucocytes. Otherwise he proved conclusively that the blood-plates existed in normal circulating blood, in a perfectly regular and definite form. In opposition to Hayem, he says that they are flat and colourless and finds no sufficient evidence that they are the progenitors of the red corpuscles. He considers that they are the chief agents in the coagulation of the blood, and that in certain conditions they form thrombi within the vessels. Further reference to his views is made below.

Laker[2] also believes that the blood-plates are distinct pre-formed elements of the blood. He calls them "Blutscheibchen," and describes them as small biconcave discs devoid of colour, most being of elliptical shape. He thinks that they are neither intermediate forms nor formed by the breaking down of other elements. Heyl and Rauschenbach have written in opposition to Bizzozero's views, especially as concerns the relation of the "Blutplättchen" to coagulation. Both affirm that they are destruction-products, but admit that they may be formed intravascularly. A comparison of the views of these three authors is given by Weigert,[3] who considers that the blood-plates seen by Bizzozero in the circulating blood were formed from the leucocytes, owing to the abnormal conditions to which they were exposed. Still another theory of the origin of the blood-plates is given by Slevogt.[4] He believes that they are formed from the red granule-balls of Semmer, which break down on the shedding of the blood. These bodies were formed by Semmer in the plasma of horse's blood, which had been prevented from clotting by means of cold. Laker[5] finds, however, that the granules are of quite a different

[1] Bizzozero, *Virchow's Archiv*, vol. xc. p. 261.
[2] Laker, *Sitzungsber. d. k. Akad. d. Wis. zu Wien*, vol. xciii. p. 21.
[3] Weigert, *Fortsch. d. Med.*, 1883.
[4] Slevogt, *Inaug. Dis.*, Dorpat, 1883 (I have only seen a reference).
[5] Laker, *Op. cit.*

nature from the blood-plates, and considers the granule-balls to be a variety of coarsely granular leucocyte.

Hlava[1] finds that blood-plates are present in the circulating blood, but in smaller numbers, and of less constant form than Bizzozero describes. They are probably the nuclei of multinucleated leucocytes which have become free. The granule-masses seen in shed blood are formed chiefly by a breaking down of leucocytes, but also to a less extent, of blood-plates. He opposes Bizzozero's views regarding coagulation and thrombosis. Halla,[2] on the other hand, holds that coagulation always starts from the blood-plates, which are probably derived from the leucocytes, though not after the blood is shed. He found that they underwent certain definite variations in disease. Lavdowsky[3] has repeated and confirmed Bizzozero's experiments, and agrees with him regarding the relation of the blood-plates to coagulation. Afanassiew,[4] from observations on the blood and bone marrow in traumatic anæmia, has formed a theory, which includes both blood-plates and nucleated red corpuscles as stages in the development of the red corpuscles. In anæmic dogs he found large blood-plates in the bone marrow similar to those in the blood, and he could trace stages in which these blood-plates became surrounded by a clear narrow band of protoplasm, which was colourless at first, but afterwards became tinted with hæmoglobin. The blood-plate, therefore, develops into a nucleated red corpuscle, and the latter becomes an ordinary red corpuscle by losing its nucleus, which once more becomes a blood-plate.

Löwit,[5] while admitting the peculiar characteristics of the blood-plates, holds that they do not exist in normal circulating blood, but are formed when it is placed in abnormal conditions, chiefly from the leucocytes. They exist first as globulin discs, which may be secreted from the leucocytes, though this is not their only method of formation. They are dissolved in the blood at the temperature of the body, and are only visible after they have passed into the granular condition, when the blood has cooled. After this they are no longer soluble when the temperature of the blood is raised to 40° C. He also claims to have formed them artificially by precipitating a solution of paraglobulin in the presence of uric acid, but Laker, who has repeated the experiment, finds that the bodies thus formed have quite different properties from the blood-plates. Lockhart Gibson,[6] in a paper on the development of the red corpuscles, discusses the nature of the blood-plates, which he calls "colourless microcytes." He believes that they are the nuclei chiefly of red corpuscles, but partly also of leucocytes, and holds that they are the agents in causing coagulation of the blood. An interesting account of the subject is given by Osler[7] in the "Cartwright Lectures" for 1886. He

[1] Hlava, *Archiv f. Exper. Path.*, 1883; *Fortsch. d. Med.*, 1883, p. 341.
[2] Halla, *Fortsch. d. Med.*, 1883, pp. 202, 479.
[3] Lavdowsky, *Ref. Jahresber. f. Anat. u. Phys.*, 1883.
[4] Afanassiew, *Deutsches Archiv f. Klin. Med.*, 1884, p. 217.
[5] Löwit, *Sitzungsber. d. k. Akad. d. Wis. zu Wien*, vol. xc. p. 80.
[6] Gibson, *Journ. Anat. and Phys.*, 1886, p. 100.
[7] Osler, "The Cartwright Lectures" in the *Medical News*, 1886.

also gives his own results of the examination of white thrombi formed on atheromatous ulcers, on the valves of the heart, in aneurisms, and in veins. He found such thrombi to be composed of blood-plates, which had become fused together, so that they were no longer recognisable as separate elements, except on the surface of the thrombi, where the individual forms were sometimes well preserved. These results are in accordance with what Eberth and Schimmelbusch[1] have experimentally proved regarding the formation of thrombi. They took the utmost precautions to obviate the objections made to Bizzozero's observations. The animal employed was wrapped in a sheet of gutta-percha and immersed in a warm bath of normal salt solution, kept exactly at the temperature of the body. The bottom of the bath was a plate of glass, which rested on the table of the microscope. An incision being made in the linea alba through the gutta-percha sheet, a knuckle of bowel was carefully pressed out into the surrounding fluid, and its mesentery was spread over a cork frame fixed on the glass plate. An immersion lens was used, and the tube of the microscope was brought into the bath. By the employment of such means they were able to see within the small vessels the blood-plates circulating with the other elements, and presenting the usual appearances. Reference to the mode of formation of thrombi will be made below.

Though these experiments are, I think, practically conclusive, yet the most recent discussion on the subject has been regarding their pre-existence in *normal* circulating blood. The question would appear, however, to be finally settled by the observations of Laker[2] on the wing of the young bat. In a thin portion of the membrane of the wing he was able to study the contents of the capillaries without the use of a cover-glass or of any medium, his observations being aided greatly by the rhythmical contractions which take place in the veins, and which cause the flow of blood in some of the capillaries almost to cease. In those capillaries he saw the blood-plates as usual. Sometimes they occurred in small groups, but this was due to their filtering through between the red corpuscles, and they had no tendency to adhere to one another. More recently still, Löwit[3] claims to have proved their absence in blood which is kept in perfectly normal conditions. His method is to receive the blood into oil of a temperature of 37° to 38° C., and keep it free from mechanical influence. In small drops of blood in these conditions he finds no blood-plates, but when the blood reaches the slide on which the oil rests they immediately appear. It appears to me, however, quite impossible to be sure of their absence, as only the margin of the drops of blood can be satisfactorily examined.

Hayem,[4] in his recent extensive work on the blood, avoids making any definite statement regarding their origin, but inclines to think that they are derived from the red corpuscles.

[1] Eberth and Schimmelbusch, *Die Thrombose*, Stuttgart, 1887.

[2] Laker, *Virchow's Archiv*, vol. cxvi. p. 28.

[3] Löwit, *Virchow's Archiv*, vol. cxvii. p. 545.

[4] Hayem, *Du Sang*, 1889.

Descriptive.—In order to see satisfactorily the characters of the blood-plates in fresh undiluted blood it is necessary to make the examination with great rapidity after it is taken from the vessels, and to employ a high magnifying power (800–1000 diameters). By taking proper precautions no more than a few seconds need elapse between the time of withdrawal of the blood and the time of its examination. Care must also be taken that the layer is sufficiently thin to allow the separate elements to be well seen. In the blood thus examined there may be seen, by careful seeking, amongst the red and white corpuscles, fairly numerous disc-like bodies having a diameter of about a quarter of that of a red corpuscle. Their outline is faintly marked, they are faintly granular, and at first their refractive index differs little from that of the surrounding serum. They have a rounded form, but whether they are really round or oval cannot be determined by this mode of examination. When seen edgewise they have the appearance of little rods or grains of corn. They are quite devoid of any yellow colour. After the red corpuscles have begun to form rouleaux the leucocytes and the blood-plates are found in the spaces between them, and have become fixed to the cover-glass. This may be proved by placing a drop of water at the edge of the cover-glass, when the red corpuscles are swept away, leaving the other elements in position. It will be seen that the blood-plates have arranged themselves in small groups, and have changed their appearance and form. A few remain isolated, but most by their aggregation have formed clusters or flocks, which generally contain about three to twenty blood-plates, whose outline at first can be clearly seen. In pathological conditions, in which their number is greatly increased, there may be as many as a hundred or more in one heap. They have now lost their rounded form and smooth outline, and have become stellate or prickly. They are also more granular-looking, and they refract the light more strongly, so that they glance in the light when they are made to pass quickly into and out of focus, and are thus easily seen. The whole surface of a blood-plate in this condition comes into focus at once, thus showing itself to be quite flat. The aggregation of the blood-plates into flocks is thus associated with change of form and increased granularity

and refractility. If individual elements be watched after they have assumed the stellate form, some may be seen to differentiate into a more or less central granular part, and a peripheral more homogeneous portion. The extent to which this differentiation takes place varies, but it is generally less noticeable than many writers appear to imply. No doubt the same change takes place in the elements in the heaps, though it is less easily watched, and to it is due in great part the granular appearance which the heaps present. In some heaps the blood-plates are fused together, in others they may be seen united by their projecting prickles, and sometimes one can make out a substance filling the interstices between them. This latter arrangement is probably a stage towards complete fusion, and is often well seen in dried specimens (fig. 6). Shortly after the formation of the heaps of altered blood-plates—generally about three minutes after withdrawal of the blood from the vessels—the formation of fibrin commences. Delicate needles may be seen to shoot out in various parts of the field, and to cross one another in all directions. At first they are tapered away at their ends, and do not form continuous lines. After examining numerous specimens, I have come to the conclusion that the earliest appearance of the fibrin needles and their closest formation are undoubtedly round the altered blood-plates (fig. 2, *b*). Areas can sometimes be found, however, free from blood-plates, in the centre of which fibrin filaments are appearing, whilst at the periphery none are yet visible, *i.e.*, all the fibrin formation cannot be traced as spreading continuously from the blood-plates. Often fibrin filaments can be seen to be continuous with the spinous processes of the blood-plates, but they have never any special relation to the leucocytes, and I have never seen any tendency of the latter to break down after the blood is shed.

As fibrin formation goes on, the heaps of altered blood-plates become more granular and amorphous looking, the outlines of the composing elements quite disappear, so that nothing but a granular mass can be seen, with small projections around the edges, which are often continuous with fibrin needles. If the process be watched longer, small vesicles are seen to form round the edges of the granular masses, and also on their surface. These are like small mucin blebs. Later, the granular heaps dis-

integrate and form débris. Sometimes the heaps decrease in size during fibrin formation, but this is much more probably due to an actual contraction and condensation than, as some suppose, to a conversion into fibrin.

It will be noticed that the most striking changes in the blood-plates take place rapidly before the commencement of fibrin formation, those following it being much more gradual.

The assumption of the stellate form by the blood-plates has been supposed to be due to part of their contents diffusing outwards—an explanation which is certainly plausible. Eberth and Schimmelbusch have shown that this change can be induced intravascularly by running a stream of cold salt solution over the mesentery of an animal. For obvious reasons it cannot be strictly compared to the crenation of the red corpuscles. The differentiation of the substance of the blood-plates seems to be due to some change in their constitution, by which the granules are allowed to come together by molecular attraction. An exaggeration of the process is seen when water or acetic acid is added to the blood. Neither of these changes can be considered a vital process, as some (*e.g.*, Hayem) suppose. I may add, that on a warm stage they exhibit no amœboid movements.

The adhesiveness which the blood-plates acquire in shed blood is a well-marked property, and to it is due in great measure their importance in pathological processes. They can be seen to stick to the cover-glass with great tenacity, as they cannot be dislodged by striking it, nor are they washed off by a stream of water, though they ultimately become broken up and dissolved by it. If a large drop of blood be placed on a slide with a sunk cell, away from the cell, and if a cover-glass be placed on the drop and pushed along till it covers the cell, it will be found that on the portion of the cover-glass corresponding to the cell there is a thin layer which contains enormous quantities of blood-plates, the reason being that all the blood-plates which are brought in contact with the cover-glass in the process of sliding adhere to it. In this way beautiful preparations may be made from normal blood.

If a drop of water be placed on the edge of the cover-glass, and allowed to mix with the blood, interesting changes follow,

which can be more readily watched if a little methyl-violet be added to the water. As is well known, the red corpuscles become decolorised and the leucocytes swell up somewhat, and the nuclei become visible. At first the blood-plates show a more definite outline, and the fibrin filaments, if coagulation have commenced, are also more distinctly seen. After a time most of the blood-plates may be seen to swell up into clear vesicles, which have at one point, either at the centre or at the periphery, a slightly granular portion, which is tinted with the methyl-violet (fig. 4). These little vesicles have a faint outline, and can only be seen on careful examination in a good light. A group of blood-plates which have undergone this change often presents the appearance of a grape-like cluster of clear vesicles with a number of small granular patches interspersed, doubtless one for each vesicle. Dilute acetic acid causes a somewhat similar change, but the nuclei of the leucocytes are more easily seen and more highly refractile, their appearance presenting a marked contrast to the altered blood-plates (fig. 5). The vesicles vary greatly in size, but the largest are sometimes 6 μ in diameter. Later some of the altered blood-plates may lose their granular portion, and they finally disappear. This shows that they are composed of two substances, one of which swells up on the application of water, and another, more granular, which is less affected. The addition of a little liquor potassæ to the water causes them to disappear more rapidly. Alcohol produces little change beyond making them more granular, and showing much more clearly the fibrin needles, if these have formed.

The changes described on the shedding of the blood can be retarded or prevented by the use of certain artificial media. Most neutral salt solutions which prevent coagulation of the blood act in this way to a greater or less extent. Certain combinations which have been found specially suitable are mentioned above. None, however, I believe, preserve all the elements quite unchanged. Hayem's solution is useful both as a medium to be mixed with the blood, and also as a fixative for dried films. According to Laker it is imperfect, as it causes the central depression of the red corpuscles to become deepened, and their rim broadened. A one per cent. solution of osmic acid

preserves the form of the blood-plates better than Hayem's solution, and by means of it measurements may be taken. In this solution, with which the proportion of blood mixed ought to be small, the blood-plates appear as small discs or lens-shaped bodies, composed of a finely granular material, but otherwise showing no structure whatever (fig. 3). Most are round, but some, especially those of larger size, are oval. In fact, in the blood of a dog which I examined, in which the blood-plates were of exceptionally large size, all the largest forms appeared to be of oval shape. (Eberth, on the other hand, says that all are round.) I have never seen any trace of concavity on the surface of the blood-plates when examined in the osmic acid solution, as is said by some to be present. On the other hand, in the solution of sulphate of soda, tinted with methyl-violet, a concavity can sometimes be seen with tolerable distinctness, but I have never seen indications of a double concavity on profile view. In short, as the result of examining them in many different ways, I believe that they are normally flat, or slightly convex, and that when a concavity is seen it is the result of a slight folding of the blood-plates. Also, most of those who have seen them in normal circulating blood agree that they have no concavity (though Laker is an important exception). Neither in fresh blood nor in preserving fluids have I seen the least trace of coloration in the blood-plates, though in osmic acid solution after a time both they and the leucocytes acquire a somewhat brownish tint. Moreover, in dried specimens stained with methyl-blue, the blood-plates are always of a pure blue colour, whereas if they contained hæmoglobin, they would show a greenish tint, the red corpuscles being of a well-marked green colour.

In the tinted sulphate of soda solution, the blood-plates appear as rounded or oval discs, with generally some irregularity of outline. They are of a pale bluish colour, and they sometimes are finely and uniformly granular; sometimes they show partial differentiation.

None of these fluids ought to be kept for a long time, and they ought to be repeatedly filtered, especially those which are coloured.

The characters of the blood-plates can be well studied in dried

films prepared and stained as described above. The following are the chief appearances met with. If the blood be mixed with osmic acid before being dried, the blood-plates are seen as circular or oval discs uniformly darkly stained throughout, and presenting no trace of differentiation or of any structure whatever. This we may consider to be the blood-plate in its least altered condition. If the film of blood be simply dried, the blood-plates have various appearances according to the rapidity with which they have been fixed in the process of drying. Some are circular as before, some are round with spinous processes, and others are distinctly stellate. Some, of all these shapes, are uniformly stained throughout, some present towards their centre a portion more darkly stained, though not sharply defined. Sometimes they are joined together by their processes, with, it may be, a faintly stained interstitial material between; sometimes they have become fused together, and form the well-known "granule-heaps," in which, however, the individual elements are much more easily seen than in the unstained condition (figs. 6, 7, 9).

Their staining reactions form a subject of great importance, regarding which there has been much variety of statement. Pouchet says that they are unaffected by staining reagents, and, therefore, like the protoplasm of the leucocytes in their chemical characters; Ranvier considers that they stain like fibrin; while Hayem finds only a trifling difference between their staining reactions and those of the red corpuscles. According to Afanassiew, they stain in the same way as the nuclei of the leucocytes, whilst Eberth and Schimmelbusch note some minor differences between them. My own results show that the conditions of staining markedly affect the result, and thus the above differences of statement can to some extent be explained.

In the first place, they differ widely from the red corpuscles as regards their behaviour to stains. In all the violet-tinted solutions mentioned above, the blood-plates are stained of a pale violet colour, whilst the red corpuscles are quite unstained. Dried films, stained with alcoholic methyl-blue, show the blood-plates of a bright blue colour, the red corpuscles of a transparent light green colour; if stained with a weak watery solution of gentian-violet, the blood-plates are a deep violet

colour, the red corpuscles almost unstained (fig. 8). Some of the differences in staining may be explained by the absence of hæmoglobin in the blood-plates, but most of them clearly indicate a wide difference in structure between the blood-plates and the red corpuscles, and I have never seen forms with intermediate staining reactions. The two elements may be stained alike if the blood be mixed with osmic acid before the film is made, and the film stained with gentian-violet.

They are evidently also different in their composition from the protoplasm of leucocytes, as they are stained deeply with nuclear stains, whereas the protoplasm is stained very feebly or not at all. Their staining reactions would indicate therefore a closer affinity to the nuclei of leucocytes, but here also differences may be made out. Thus, in double staining with fuchsin and methyl-blue the blood-plates are of a faint violet colour, whilst the nuclei are blue and more distinct, and in double staining with gentian-violet and methyl-blue, the blood-plates are violet and the nuclei blue. The blood-plates are always stained of the same colour throughout, and, though sometimes a small area is more darkly stained, they show no internal structure or network. The nuclei of the multinucleated leucocytes, on the other hand, often show a chromatin network, the interstitial substance being unstained or even stained of a different colour, as in the fuchsin-methyl-blue staining, where it is of a pale pink colour, the chromatin being bright blue. I may say also that they differ from the nuclei of the nucleated red corpuscles of the bone marrow, which generally show a well-marked chromatin-reticulum and stain like the nuclei of leucocytes, though rather more deeply as a rule. We must therefore conclude that in their structure and chemical composition they differ from the other elements of the blood or parts of these elements.

The average size of the blood-plates in normal conditions in the human subject is about 2 μ, though considerable variations both above and below that size are found (1·8 to 3·6 μ, Afanassiew; 1·5 to 3·5 μ, Osler). The largest blood-plates which I have seen were in the blood of an anæmic dog, where some reached 5 μ diameter. There is pretty general agreement that in different animals the average size varies propor-

tionately with the size of the red corpuscles. Also, in animals with nucleated red corpuscles, stuctures are present which adhere together when the blood is shed, and which are generally described as nucleated blood-plates (see the papers of Hayem, Bizzozero, Eberth and Schimmelbusch). The average number of blood-plates in health may be said to be about 200,000 to 250,000 per c.mm., though considerable margins on either side of these figures must be allowed. We must therefore avoid speaking of their number as increased or decreased, unless it is markedly so, yet it will be found that in various pathological conditions their number is altered in a very definite manner, and in some cases to a great extent. In different animals their number varies much, but I have found it to be pretty constant in the same animal from time to time.

From the above account it follows that the blood-plates are separate elements of the blood with characters peculiar to themselves. Whether they may be developed from one of the other elements will be considered later. Their variations in disease, and their supposed relation to the development of the red corpuscles accordingly present questions of great importance.

Though my work has been chiefly on these two subjects, an account of the blood-plates would not be complete without some reference to the part they play in coagulation and thrombosis. I shall simply mention the chief facts, and shall not attempt a full discussion of the subject.

The theory that the blood-plates are the chief agents in the process of coagulation of the blood has several important facts in its favour. They are stated by many to be the only elements which alter their morphological characters before and during the process of coagulation. This is in antagonism to the theory of Schmidt and his followers, who maintain that a very large number of leucocytes break down when the blood is shed. This destruction of leucocytes has never been actually seen under the microscope, so far as I know, and its occurrence is denied by most modern observers (*e.g.*, Hayem, Halla, Laker, Eberth, and many others). Moreover, in whatever way we examine the blood, by receiving it immediately into fixing fluids, by dried films, or without any fixing or diluting medium, the leucocytes always appear to be in the same proportion. Bizzozero

says that also within the vessels their proportion appears to be the same. On the other hand, that the blood-plates do change their form when the blood is shed, is a fact admitted by all. Also, as described above, the fibrin filaments are generally densest around the altered blood-plates, and are often continuous with the small projections at their margins. In pathological conditions in which the blood-plates are very numerous, the fibrin network is generally very dense, and, further, the fibrin filaments are generally scanty when there are few blood-plates. This rule is not without exception, however, as I have seen, *e.g.*, in acute pneumonia, a very dense fibrin reticulum associated with a scarcity of blood-plates. Further, various methods, which prevent or delay coagulation of the blood, retard the changes in the blood-plates. Such methods are, the addition of neutral salt solutions to the blood, exposing the blood to a low temperature (Hayem), the addition of peptone to the blood (Bizzozero), and, lastly, Haycraft's method of receiving the blood into castor-oil (Gibson). Bizzozero whipped freshly shed blood with fine threads, and found that first they became covered with blood-plates, and afterwards fibrin was deposited upon them, and he was able to watch an analogous process under the microscope. By ligaturing portions of blood-vessels and examining the contained blood at intervals, he found that, so long as the blood remained fluid, the blood-plates retained their normal form, but when coagulation commenced their form had begun to change. He further made experiments by means of a "protoplastic" fluid capable of coagulating on the addition of fibrin-ferment. To various samples of this fluid he added saliva, portions of lymphatic glands, spleen, &c., and found that threads covered with blood-plates by whipping blood were the most active agents in causing the coagulation of the fluid. He does not deny the possibility that other elements may have the power of inducing coagulation, but considers, for the above reasons, that the chief rôle is played by the blood-plates. Hayem, who holds the same opinion, still admits that leucocytes may furnish some material instrumental in bringing about coagulation, as in lymph, spontaneously coagulable outside the body, he found no blood-plates present. In the blood, however, he believes that the blood-plates are the chief agents

Eberth and Schimmelbusch, on the other hand, consider the coagulation of the blood to be a process of crystallisation which has no relation to the blood-plates.

With regard to the part they play in thrombosis, there is much greater unanimity of opinion amongst those who are competent to judge. The four last-mentioned authors all agree that if the blood-plates within the vessels be brought into contact with a foreign body or the vessel wall in an abnormal condition, they undergo the same changes as they do outside the vessels, heaping themselves together by their adhesive properties, and forming a granular mass which may come to form a thrombus. If a thread be held for a short time in the blood flowing from an artery, and be washed immediately afterwards in Hayem's solution, it will be found on microscopic examination to be covered with blood-plates (fig. 10). I have been much struck with the myriads of those bodies which are found adhering to the threads when these have been in the flowing blood for only a few seconds. So, also, I have inserted a fine silk thread through the wall of a vein, bringing it out again at some distance (as Bizzozero did), and have found after a few minutes that it is covered with a colourless layer on whose surface individual blood-plates can be clearly seen, but deeper they are fused together and their outlines are indistinguishable. Nothing can be more convincing of the possibility of their being important factors in certain pathological processes.' Eberth and Schimmelbusch have studied experimentally the production of thrombi in the small and large vessels, both of cold-blooded animals and of mammals. The thrombi were produced by injuring the vessel walls in various ways. In the case of the small vessels, the process was watched under the microscope, as described above; in the case of the large vessels, the portion of vessel injured along with the contained blood was hardened and sections were cut. In all cases they arrived at practically the same conclusion, viz., that the condition necessary to the formation of the ordinary white thrombi is that blood-plates be brought into contact with abnormal vessel walls. In normal conditions, except at the branching of vessels where there are eddies, the blood-plates circulate with the red corpuscles in the axial stream, but if through any cause the steam be slowed

sufficiently the blood-plates appear at the periphery. For example, if the vessel wall be painted with caustic, so that the internal coat is cauterised, yet remains in position, no thrombus may be formed, but if it becomes detached, and projects into the stream, a thrombus is formed around it. Again, if the internal coat be ruptured by a ligature which is afterwards removed so that the stream through the vessel is restored, a thrombus arises round the edges of the ruptured coat, which constrict the lumen of the vessel. In such thrombi the presence of leucocytes, red corpuscles, or fibrin threads, is accidental and not essential. These results are in accordance with the known properties of the blood-plates, and their number is certainly sufficient for that purpose. In the same way it has been experimentally proved that the blood-plates have for similar reasons a most important function in the closure of wounds in vessels, and in the arrest of hæmorrhage.

EXPLANATION OF PLATE VI.

Fig. 1. Blood-plates from normal human blood, a few seconds after being removed from the vessels. Some are just beginning to alter their outline. *r*, red blood-corpuscle.

Fig. 2. Blood-plates which have changed their form and fused themselves into a heap. In (*a*) they are granular, but the outlines of many can be seen. In (*b*) fibrin formation has commenced, and some of the fibrin filaments are continuous with the small projections of the blood-plates.

Fig. 3. Blood-plates from the blood of a dog, in osmic acid solution. They appear as small discs of round or oval form with a faintly granular appearance.

Fig. 4. Blood-plates which have been treated with water tinted with methyl-violet. They have changed into small vesicles with a small granular body at one point, which stains more deeply. *l*, leucocyte.

Fig. 5. Blood-plates treated with dilute acetic acid. A group has become a cluster of clear vesicles with small granular points. Contrast with the nuclei of the leucocyte (*l*).

Fig. 6. Portion of a dried film stained with gentian-violet. The blood-plates are stained deeply and of angular outline, with, in some places, a faintly stained interstitial substance between. A red corpuscle (*r*) is faintly stained.

Fig. 7. Portion of dried film stained with fuchsin, showing blood-

plates of various appearances. Some have partially differentiated into a central more darkly stained portion. *r*, red corpuscle, *l*, leucocyte.

Fig. 8. Portion of dried film stained with gentian-violet, showing the difference in appearance between the blood-plates and the red corpuscles. A nucleated red corpuscle (*n. r.*) has been introduced for comparison.

Fig. 9. Large group of blood-plates from the blood of a dog. They have probably been in contact with one another, and have been separated in the formation of the film. Many remain connected by delicate threads. Dried preparation. Gentian-violet.

Fig. 10. Silk fibres which were held for a few seconds in the flowing arterial blood of a dog and examined in Hayem's solution. They are covered with collections of blood-plates. Isolated red corpuscles are lying between.

In these figures the magnifying power is about 900 diameters; in figs. 7 and 9 it is a little higher.

(*To be continued.*)

AN IMPROVED METHOD OF PREPARING LARGE SECTIONS OF TISSUES FOR MICROSCOPIC EXAMINATION. By J. C. WEBSTER, B.A., M.B., *Assistant to the Professor of Midwifery in the University of Edinburgh.*

(Read before the Pathological Club.)

HITHERTO we have employed two methods of preparing large sections for microscopic study, viz., the freezing and the celloidin. In the former the "Hamilton" or "Bruce" microtome is used, and in the latter the "Schanze." Each of these processes has connected with it certain difficulties which limit the range of its employment.

The objections to the first method are the following:—

a. It is impossible to prepare delicate or friable tissues in large thin sections, because, after being cut they either break into pieces when placed in water or during the mounting process get torn and destroyed. The placenta, for example, cannot be cut into sections suitable for the finest microscopical work, as the villi and the blood corpuscles in the maternal sinuses are almost entirely scattered when placed in fluid.

b. The relations of parts cannot be preserved. Thus, for example, one cannot mount undisturbed a section through bladder and uterus or through brain and membranes.

c. The difficulties and discomforts connected with the working of a large freezing microtome are considerable.

The objections to the second method are:—

a. It is impossible to prepare sections thin enough for examination by high powers. Those which can be made are only fit for study with low powers or for lantern demonstration. This is the case with even the most easily cut tissues.

b. The microtome employed—the "Schanze"—is complicated and expensive; its knife is with great difficulty kept sharpened, and does not always cut large sections in slices of uniform thickness.

c. The materials used in preparing the tissues for cutting are expensive.

The method which I am about to describe is not only free from these important objections, but possesses several distinct advantages.

TECHNIQUE.

1. *Preparation of Tissues.*—Tissues may be hardened by any of the known methods, the last stage, however, being a twelve or eighteen hours' soaking in absolute alcohol. The following method gives splendid results:—

Place the fresh tissue in a boiled saturated solution of corrosive sublimate for one night. Then wash in water, and place for twenty-four hours in a mixture of one part of methylated spirit and two of water; then in a mixture of equal parts for two days. Gradually increase the proportion of spirit in the mixture until at the end of eight or ten days the tissue can be placed in pure spirit, where it can be left until it is desired to examine it. A slice is then cut $\frac{3}{16}$ to $\frac{7}{16}$ inch in thickness, and placed for twelve to eighteen hours in absolute alcohol. It is then soaked in pure naphtha for twenty-four hours. It is then placed in a mixture of equal parts of naphtha and soft paraffine, and exposed to a temperature of about 115° to 120° F. in a water-bath for eighteen to twenty-four hours. (The advantage of naphtha over turpentine is that it dissolves paraffine at a much lower temperature, thereby allowing the water-bath to be kept in such a condition that there is no danger of over-heating the specimen.) Throughout this process the temperature is kept lower than in the ordinary methods. (The advantage of naphtha over chloroform and xylol is its cheapness.) It is next placed in melted soft paraffine, and kept in the bath at about the same temperature for twenty-four hours. Then, it is changed to a mixture of one part of soft and four or five parts of hard paraffine for the same length of time at a higher temperature. (Care must be taken that the thermometer does not rise above 140° F.)

2. *Embedding.*—Paper or thin cardboard boxes, about 1 inch in depth, and slightly more than large enough to hold the tissue may be used. Nearly fill with a warm melted mixture of soft

NOTE ON THE SKIN AND SCALP OF THE NEGRO FŒTUS. By Arthur Thomson, M.A., M.B., *Lecturer on Anatomy, University of Oxford.* (Plate VII.)

The presence of pigment in the skin of the negro fœtus has long been a matter of speculation.

Since Blumenbach, the founder of modern anthropology, first treated the subject in a scientific manner, subsequent observers, such as Camper, Hunter, and more recently Waitz, have stated on what was apparently more or less good authority, that the negro fœtus was born white,[1] and have advanced this fact as a proof that the action of light and air was one of the factors necessary to the production of colour.

In recent years, observers have stated that whilst the negro fœtuses at birth were lighter in colour than what they were, say at the end of a week, yet the fact has been admitted, that even at birth they could readily be distinguished by their dusky hue when placed side by side with the children of white parents though as a matter of fact this distinction became a difficulty when half-breeds were examined.

Dr Morison of Baltimore in the *Monatsheft f. prak. Dermatologie*, 1889, vol. ix. p. 480, has published a paper on this subject, wherein he states that he has found evidence of pigment in the skin of an eighth month negro fœtus, and has also been able to demonstrate its presence in another fœtus of nine months. As the subject is one which I have been working at for some time, and as these observations have anticipated some of the results which I hope presently to publish on the skins of different races of men, I thought the Society might like to see some specimens which have a bearing on this subject. The sections displayed were obtained from portions of the skins of negro fœtuses of the ages of five and eight months respectively, and I must here express my indebtedness to

[1] An "Inaugural Dissertation," John Hunter; *The Anthropological Treatises of Blumenbach and Hunter*, London, 1865, p. 372; *Anthropology of Primitive People*, Waitz, London, 1863, vol. i. p. 98.

Fig. 1

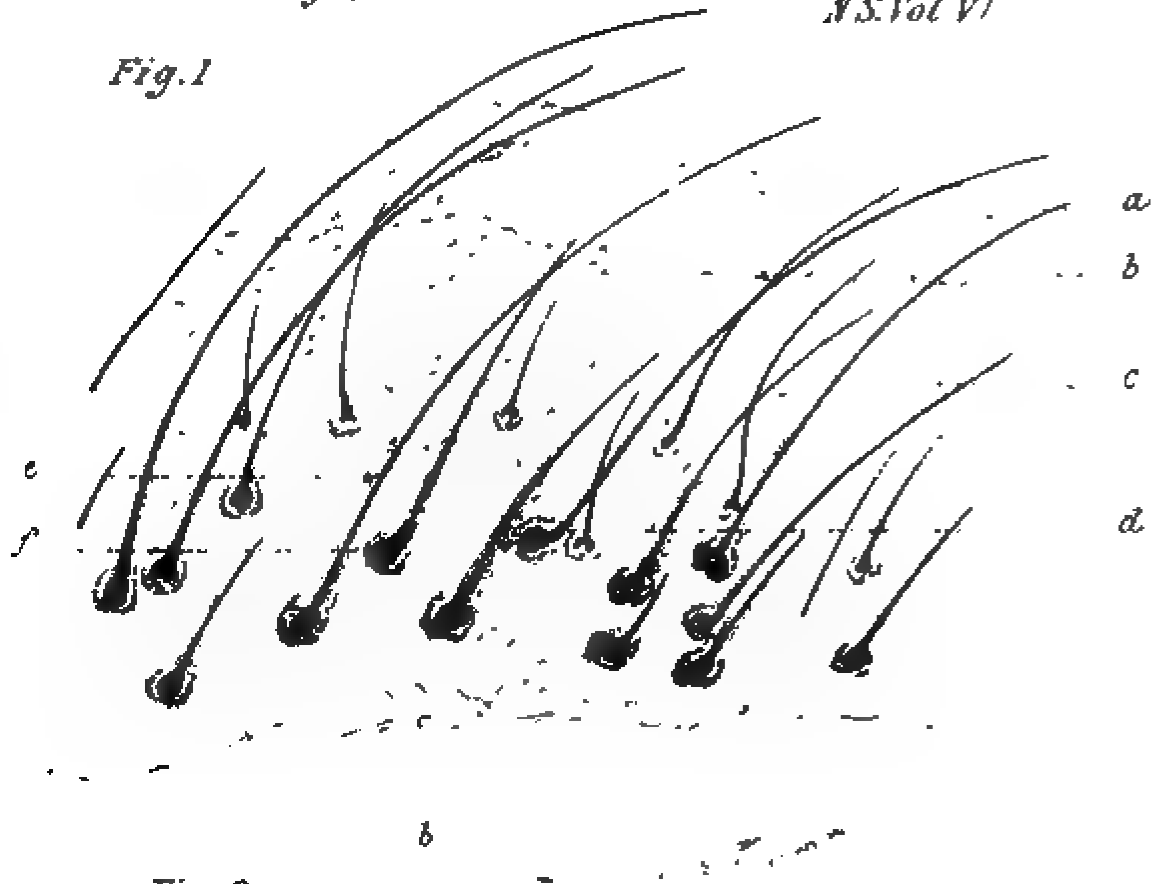

Fig. 2.

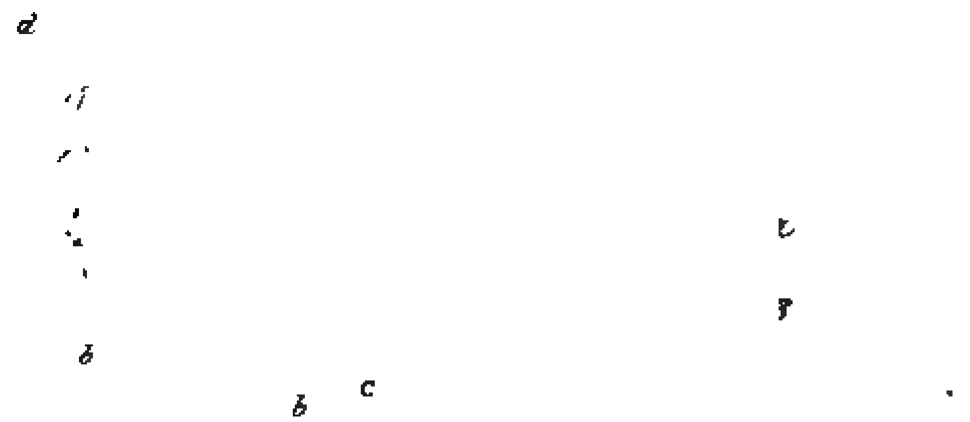

Fig. 4.

Professor Moseley for his kindness in furnishing me with the material from which the sections have been cut.

As will be seen in the sections (unstained) of the skin and scalp of the fifth month fœtus, there is distinct evidence of pigmentation of the rete mucosum. It appears as a faint yellow stain in the skin, and, curiously enough, is more pronounced in the scalp, where its presence is indicated by a stain of a deeper hue, with just a suggestion of granulation in the deeper layers of the mucosum. In the ninth month fœtus, on the other hand, the pigment is easily recognised as a granular layer in the deeper cells, resembling closely the arrangement with which we are familiar in the adult, with this difference, however, that the granular matter is not deposited in such quantity in the cells.

In the sections prepared from this fœtus, the skin appears more deeply pigmented than the scalp, a condition which more or less maintains in the specimens I have examined of the skins and scalps of coloured races.

Turning now to the scalp of the fifth month fœtus, another interesting point is to be noted,—a feature which is best demonstrated by studying thick sections of the scalp which have been rendered transparent by toluol or clove-oil; by this method we are enabled with a low power to study the disposition and arrangement of the hair follicles.

In the specimen which I show you, the curved character of the follicles, as described by Professor Stewart, is seen, but if the base of the follicle be carefully examined, the bulb of the hair will be seen enveloped as it were in a pocket of interlacing pigmented matter (fig. 1). A further examination of thin sections with a high power, reveals the fact that this appearance is due to the presence of pigment *between* the large cells which surround the papilla, cells which, on the one hand, are continuous with the cells of the rete mucosum of the outer root sheath, on the other with those which, advancing forward on the surface of the papilla, become modified to form the hair. As these cells of the hair bulb are traced forward on the papilla, the pigment which appears *between* the lower cells *(intercellular)* (fig. 2), becomes, in the older cells, absorbed in a granular form *within* the cells *(intracellular).* In no other specimen which

I have examined have I seen this appearance so well marked, though in the scalp of an adult Lascar (fig. 3), and a Bengali (fig. 4), I have seen indications of a similar disposition of the pigment. So far as I have been able to discover, the pigment, which lies between the cells around the lower part of the papill and between the cells of the lower part of the outer roo sheath, is free, and is not confined by any cellular substan other than the cells between which it lies; it might be w described as resembling a burnt-sienna brown injection of t intercellular channels of the lower part of the sheath and ce surrounding the papilla. There is no evidence that it is c tained within the so-called "wandering cells," about which much has recently been written.

As will be seen, the sections of the scalp of the tenth mo negro fœtus do not display this very characteristic appeara and this fact would suggest that the deposition of the pigm in this peculiar manner is in some way associated with incre activity in the development of the hair.

As the investigation on which I am at present engage necessarily hampered by scarcity of material, I would este a favour if any members of the Society who have portio skin or scalps of coloured races of men in their possession, w favour me with the use of such specimens. Meanwhile, I serve any other observations on the question of pigmentati man until such time as I am enabled to complete the enqu

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EXPLANATION OF PLATE VII.

Fig. 1. Thick section of Scalp of Negro Fœtus of 5 months. objective of Ross. Ocular No. 2 (Zeiss.) Camera lucida dr *a*, stratum corneum. *b*, rete mucosum; *c*, cutis vera; *d*, subcut layer; *e*, hair follicle; *f*, hair bulb surrounded by a netw anastomosing processes of pigment in the lower part of the foll

Fig. 2. Section of base of hair follicle of Scalp of Negro Fo 5 months. Obj. D. Oc. 2 (Zeiss.) Camera lucida. *a*, out sheath; *b*, pigment *between* the cells of the outer root sheath the papilla; *c*, at this point the pigment lies *in* the cells; *d*, coat of follicle.

Fig. 3. Section of the base of the hair follicle of Scalp of a

Lascar. Obj. D. Oc. 2 (Zeiss.) *a*, outer root sheath; *d*, dermic coat of follicle; *b*, pigment seen deposited in an anastomosing series of channels around the papilla; *c*, the pigment is seen in a granular form ***within*** the cells of the hair.

Fig. 4. Section of base of follicle of hair of Scalp of adult Bengali, low power. *a*, outer root sheath; *d*, dermic coat; *b*, pigment seen scattered among the cells of outer root sheath at the base of hair follicle.

THE SYLVIAN FISSURE AND THE ISLAND OF REIL IN THE PRIMATE BRAIN. By D. J. Cunningham, M.D., *Professor of Anatomy, University of Dublin.*

In the following paper I purpose stating very briefly some of the results I have obtained in connection with a somewhat prolonged investigation into the anatomy of the Sylvian fissure and the island of Reil in the primate brain. I publish these in abstract in the present instance, but before very long they will be dealt with *in extenso* in Cunningham Memoir, No. VII. (*Royal Irish Academy*).

The island of Reil in the human brain is covered in typical cases by three opercula, viz., an upper or *parieto-frontal*, a lower or *temporal*, and an anterior or *fronto-orbital*. The anterior operculum is further subdivided into two distinct portions. One of these appears on the external face of the adult brain, and may be called the *frontal operculum* (pars triangularis of Eberstaller; "cap" of Broca), whilst the other is on the orbital face and may therefore be designated the *orbital operculum*.

These four opercula are separated from each other by the limbs of the Sylvian fissure. The *posterior horizontal limb* intervenes between the temporal and parieto-frontal opercula; the *anterior ascending limb* separates the parieto-frontal from the frontal operculum; and the *anterior horizontal limb* intervenes between the frontal and orbital opercula.

There has been a great deal of loose description in connection with the anterior limbs of the Sylvian fissure, and the reason of this is obvious. Different authors have had different ideas as to the characters by which an "anterior limb" should be judged. Only two have condescended to give a sufficiently precise definition. Pansch considers it a requisite that the "anterior limb" should cut right through the operculum. Eberstaller adds a still further requirement, viz., that the incision through the operculum should be so complete that it should reach the furrow surrounding the island of Reil. We hold to the latter definition.

In addition to the ascending and horizontal anterior limbs, there may be two others cutting through the short orbital

operculum. These have previously been noted by Eberstaller, whilst Zuckerkandl has observed the outer of the two.

The four anterior limbs are not constant in their relations or presence. No less than fifteen different combinations occur.

In the Negro brain there appears to be a deficiency in the orbital operculum; and the anterior orbital limbs of the Sylvian fissure which incise it are less frequently present than in the European brain.

One of the most remarkable characters in the cerebrum of the Orang and the Chimpanzee is the total absence of the frontal and orbital opercula. The temporal and parieto-frontal opercula are alone present.

There is a so-called anterior limb of the Sylvian fissure, but it hardly comes within the definition that we have given of an "anterior limb." It bounds the parieto-frontal operculum in front, it is true, and the fore-border of this operculum forms its superficial wall. It cuts into the hemisphere very obliquely, and the surface of its deep wall is carried almost continuously into the surface of the island of Reil.

It is curious that while the anthropoid should be so absolutely destitute of a frontal and an orbital operculum, there are many of the lower apes (*e.g.* Baboons, Macaques, &c., &c.,) which show a faint trace of the orbital operculum.

But it may be asked why we have so decidedly stated that the frontal operculum (pars triangularis) is absent in anthropoids, seeing that we might very well suppose that it was merely fused with the fore part of the parieto-frontal operculum. This is no doubt the view of those who hold that the so-called "anterior limb" of the Sylvian fissure is homologous with the anterior horizontal limb in man, but it is an erroneous supposition. The fact is, that if we are to regard this "anterior limb" of the Sylvian fissure in the anthropoid brain as homologous with anything, it must be with the ascending limb of the human brain, and for this reason: *the part of the island of Reil which corresponds to the frontal operculum or pars triangularis in man is absent in the anthropoid ape.*

There has been a great deal of discussion upon the third frontal convolution, and its deficiency or absence in the Ape. This is a question into which I am not prepared to enter at

present; but this much I may say, viz., that the chief difference to be noted in this region between human and anthropoid brains is, that in the latter there is no undermining of this convolution by the island of Reil in front of its pars basilaris.

But, further, another very striking difference between the human cerebrum and the anthropoid cerebrum is to be found in the relative size and in the position of the island of Reil.

If we take the length of the lateral surface of the hemisphere as being equal to 100, the average length of the insula in the European is 29·6; in the Negro, 28·3; in the Orang, 21·5; and in the Chimpanzee, 18·2.

Hefftler, Guldberg, and Eberstaller have pointed out that in man the island of Reil is divided by a well-marked furrow, termed the sulcus centralis, which has the same direction, and lies in the same plane as the fissure of Rolando, into a fore part or pars frontalis, and into a posterior portion or pars temporo-parietalis. The pars frontalis is the larger of the two, and is connected solely with the frontal lobe. The pars temporo-parietalis is connected with the parietal and temporal lobes. In the anthropoid ape, if there is any part of the pars frontalis present, it is merely that portion of it which Eberstaller terms the gyrus tertius.

It is extraordinary that in the lower apes the island of Reil should present a greater antero-posterior diameter than in the anthropoid apes. In the Macaque it is 24·9; Hamadryas, 23·9; Baboon, 27·9; Mangaby, 25·3; Cebus, 25·5.

In the human brain, if we consider the lateral length of the hemisphere to be 100, the length of the frontal operculum is 6·9, and from the period of its full development in the first year of life up to the adult condition, it does not vary. On the left side, however, it is longer than on the right side, in the proportion of 8 to 6·1. Further, it appears to be shorter in the Negro than in the European.

Topography of the Sylvian Fissure.—The point at which the trunk of the Sylvian fissure appears on the outer face of the hemisphere may be termed the "*Sylvian point.*" The position of this in the human brain varies somewhat at different periods of growth. It makes a slight advance in a forward direction as growth progresses, and it may be said to become finally fixed in its position about the eleventh year. In the adult male it is

placed slightly in front of the position which it holds in the female. There is apparently no difference in this respect between the right and left hemispheres. In the Negro it is placed further back than in the European.

In the Orang, Chimpanzee, and also in the lower apes, the "Sylvian point" is placed behind the corresponding point in the human brain, and in this respect the apes resemble more the new-born child than the human adult.

It is well known that the posterior horizontal limb of the Sylvian fissure in the last month of intra-uterine development, in the new-born infant and in the young child, lies considerably above the level of the squamous suture, but the relative position which it occupies with reference to this suture at different periods of life has not hitherto been made out.

In arriving at the following results, the measurements of the depth of the parietal and temporal lobes, and of the position of the Sylvian fissure with reference to the squamous suture, have been made along a line drawn downwards from the summit of the anterior central convolution, at right angles to the longest antero-posterior axis of the hemisphere. The entire breadth of the hemisphere along this line, from the superior border to the infero-lateral border, is reckoned as being 100.

In the adult the fissure was found to be in an equal number of cases a short distance above, a short distance below, and immediately subjacent to the suture.

In five hemispheres, *from children* ranging *from* 11 *to* 15 *years*, it was found to be in every case above the suture, the average relative distance being 3·3.

In five hemispheres, *from children* ranging *from* 4 *to* 5 *years*, the relative distance of the fissure above the squamous suture was 6·5.

In three hemispheres *from children* in the first year of life, the relative distance of the fissure above the suture was 13·6.

In six hemispheres from *the full-time fœtus*, the relative distance was 20·3.

In four hemispheres *from fœtuses* ranging *from* 7½ *to* 8½ *months*, the relative distance was 24.

To account for this difference in the position of the Sylvian fissure, with reference to the squamous suture at different periods

of growth, it has been supposed that, in addition to the marked changes which occur in the position of the suture itself, there is a slipping round of a portion of the outer surface of the temporal lobe so as to take up a position on the base of the cranium coincident with the marked expansion of the cranial floor of the young skull. In other words, that the infero-lateral border of the hemisphere becomes more elevated at the expense of the outer surface of the temporal lobe. This is a highly ingenious theory, and at first I was inclined to accept it; but, as my investigation advanced, I saw that it was untenable, and for this reason, that throughout all periods of growth the same sulci and the same convolutions of the temporal lobe lie between the Sylvian fissure above and the infero-lateral border of the hemisphere below.

The growth-change in the position of the suture is very marked. At first the squamo-zygomatic bone is low and does not override the lower border of the parietal, but, as growth advances, it extends more rapidly than the parietal bone, and ascends so as to overlap it to a considerable extent. The sutural line is always regarded as coinciding with the upper border of the squamous bone. The proportion of cranial vault above and below the suture line in the adult is 75–25, whilst in the last month of fœtal life it is 81·7–18·3.

But great as this growth-change is, it is more than equalled by that in the position of the Sylvian fissure on the surface of the hemisphere. The fissure descends rapidly during infancy and early childhood, so as to increase the depth of the parietal lobe and diminish that of the temporal lobe. The following are my results in this field:—

	Parietal Depth.	Temporal Depth.
Adults, ...	69·1	30·9
From 11 to 15 years, .	69·1	30·9
From 4 to 5 years,. . .	65·7	34·3
First year of life, . .	63·9	36·1
Full-time fœtuses, . .	61·6	38·4
7½ to 8½ month fœtuses .	61	39·0

There is apparently no difference in this growth-change between the male and the female, but the left hemisphere lags slightly behind the right hemisphere all through.

In the first stages of the covering-in of the Sylvian fossa, the temporal operculum is much more energetic in its growth than the parieto-frontal operculum which grows down to meet it. Before long, however, the tables are turned, and the parieto-frontal takes the more prominent share in the enclosing of the insula, and there cannot be a doubt but that it is this excess of growth-energy, carried on through infancy and early childhood, which leads to the depression of the Sylvian fissure.

I shall not, in the present instance, deal with the topography of the anterior limbs of the Sylvian fissure.

Length of the Posterior Horizontal Limb of the Sylvian Fissure.—Eberstaller has stated that the Sylvian fissure is longer in the left hemisphere than in the right, and also longer in the female than in the male.

With the first part of this statement I entirely agree. Taking the lateral length of the hemisphere as 100, the length of the fissure on the left side of the adult brain is 28, whilst on the right side it is 24·4. This difference can be noted at all stages of growth.

I find little difference, however, between the relative length of the Sylvian fissure in the male and the female, and what difference there is seems to be in favour of the male.

Sylvian Angle.—By the "Sylvian angle" I mean the angle which is formed by the posterior horizontal limb of the fissure with a line drawn at right angles to the longest antero-posterior diameter of the hemisphere.

In the adult the average Sylvian angle is 67°·8, and there appears to be little or no difference in this respect between the male and the female. In the left hemisphere, however, the angle (70°·4) is more open than on the right side (66°·3), and this is a difference which exists at all periods of life. In children and infants the angle is more acute. In full-time fœtuses it was found to be 62°·1. Unlike the Rolandic angle, the Sylvian angle does not appear to be affected by the form of the head.

The foregoing is to be regarded as the barest possible outline of my results. I have avoided entering upon details in regard to methods employed, and the number of hemispheres examined in each group. With some additions, the brains and specimens which I have studied are the same as those which I used in connection with my recent investigation into the anatomy of the fissure of Rolando.

THE AUDITORY CENTRE. By JOHN FERGUSON, M.A., M.D., L.R.C.P., *Demonstrator of Anatomy, University of Toronto Medical College.*

THE exact position of the auditory centre has been a subject of much dispute. The results arrived at by experiments on animals are open to several objections; and while they assist in locating this centre, the most valuable experiments are those performed on the human subject by disease. As every case therefore is of the utmost importance, no opportunity should be let slip, in gathering together that accumulation of observations which renders a topographical diagnosis of intracranial diseases a possibility.

As the case from which the following observations are drawn is a very interesting one, the leading points in the case shall be detailed *seriatim*:—

The patient, a young man, was of a very strumous constitution, and with a family history of scrofula and phthisis. For a period of eight years he had suffered with a chronic otitis media in the right ear. The hearing on this side was latterly wholly lost, when the vibration proceeded from without the ear, but was slightly retained to vibrations conducted through the solid media of the bones.

For two years prior to the death of the patient there were symptoms of a cerebral tumour situated in the right temporo-sphenoidal region. There were convulsive movements, with auditory auræ, both being referred to the left side. Hearing on the left side became gradually lost, and for at least six months was entirely gone, though the auditory auræ were still present.

The post-mortem revealed a large tumour in the first and second temporo-sphenoidal convolutions on the right side, destroying the first entirely, and the second slightly.

Here we have the right ear rendered deaf by disease in the middle portion, though still connected with the opposite hemisphere, which was found healthy. The auditory nerve connecting the right ear and left hemisphere was in a state of functional activity, as shown by the test for sound through the solids of the head. The left ear was rendered deaf by disease of the right first temporo-sphenoidal convolution. Hearing was

never restored by compensation. Why the hearing in the left ear never returned by compensation, though the left hemisphere was normal, is difficult to account for. The most reasonable explanation in this case is the fact that the right ear had been so long useless that its co-educating influence was absent. When the tumour on the right side of the head had destroyed the hearing in the left ear, the right ear had already long been useless as an organ of hearing. In this way there was a period of total deafness, which continued till the death of the patient.

On the other hand, it might be that the left temporo-sphenoidal lobe, though it appeared healthy, had undergone some minute change, owing to the deafness in the right ear from the otitis, that prevented it establishing a compensation with the left ear which was normal.

The importance of the case, however, rests entirely in the proof it affords of the location of the centre for hearing, in the first temporo-sphenoidal convolution of the opposite side to that of the ear affected.

Notice of New Book.

Annual of the Universal Medical Sciences: a Yearly Report of the Progress of the General Sanitary Sciences throughout the World. Edited by CHARLES E. SAJONS, M.D., and Seventy Associate Editors, assisted by over Two Hundred Corresponding Editors, Collaborators, and Correspondents; Illustrated with Chromo-Lithographs, Engravings, and Maps.

THE issue of 1890 consists of five handsome octavo volumes, with good paper and good print, published by Davis of Philadelphia, and is a good illustration of American energy, talent, and editorial capacity to avail itself of the facilities which modern intercommunication affords for collecting and redistributing information from and to all parts. The work surprises at once by the amount of new matter which, in all the various subjects, is being poured every year into the treasury of knowledge, and by the care and organisation by which it has been brought together and set forth in these volumes. The issue for the year comprises some eighty-five departments or subjects, with an Index to each volume, and an elaborate General Index in the fifth volume, by Dr Witherstine of Philadelphia. The subjects most related to the work of this *Journal* are Embryology, Anomalies, and Monstrosities, by Drs Sudduth and Sangrel of Philadelphia; Histology, by Dr Frank Brown of Detroit; Physiology, by Howell of Ann Arbor; and Anatomy, by Dr Forbes of Philadelphia. The last-named subject is less handsomely treated than any other in the series. We are glad, however, to see mention of Anderson and Makin's "Cranio-Cerebral Pathology," Griffith's "Anatomy of the Prostate," Bland Sutton's "Nature of Ligaments," and a few other papers from this and other journals. Altogether, the *Annual* is far the best and most complete compendium in our language of the Medical Sciences, and is invaluable as a work of reference. We heartily wish it success, and hope for rather more liberal allowance to Anatomy in the future.

Journal of Anatomy and Physiology.

A MODE OF DEMONSTRATING THE GROSS STRUCTURE OF THE EYE-BALL.

By T. P. ANDERSON STUART, M.D., *Professor of Physiology, University of Sydney, N.S.W., Australia.*

I AM sure that in very many cases students never see, in such a way as to grasp it, much of the internal anatomy of the eye-ball, simply because the lens and its capsule, the vitreous body and its hyaloid membrane, and the suspensory ligament are all so difficult to see aright, except when floating in water, and even then, being colourless, they are not easily visible.

It occurred to me some years ago (1885) that if the mass were stained much of this invisibility would be set aside. The eye which I for the most part use for these demonstrations is that of the full-grown ox as it is commonly killed in Sydney—some four years old. Young eye-balls are soft of tissue and do not bear handling so well as older ones. It is needless to add that I use, or have used, the method on eyes of all sorts, and find it equally applicable to all. Still I recommend the adult ox-eye as easily procurable, large of size, and withstanding much violence during manipulation.

The mode of demonstration most profitable is to take out what I speak of as the "eye-kernel." This consists of the parts enumerated in the first paragraph, and when this has been studied the student is in possession of a wonderful deal of the eye's anatomy.

To extract the eye-kernel it is best that the eye-ball should be from one to three days old, according to the season. Then the sclerotic is cut equatorially with fine blunt-pointed scissors, and the anterior half gently pulled off, to disclose the ciliary muscle, &c. The choroid is treated in the same way, and now,

probably, the eye-kernel drops out *en masse*. The ciliary bodies, iris, anterior chamber, &c., are all beautifully seen in the parts remaining; but I wish to speak specially only of the eye-kernel.

The eye-kernel should be dropped into ordinary water, rinsed, and then transferred *en masse* to a staining fluid. The various aniline stains may be used, but I have found strong picro-carmine solution better, upon the whole, than any other, for, after the eye-kernel has been from one to three minutes in picrocarmine and then has been washed in copious water, the yellow is largely dissolved out and the carmine remains permanently. I find generally that to use a strong stain for a short time, and then to wash, gives better results—and, of course, more quickly—than a weaker stain for a long time.

In this way the hyaloid membrane, the suspensory ligament, and the lens capsule are beautifully red-stained. The whole eye-kernel obtrudes itself upon our notice as it never did before, and a certain differentiation of the colour of its different parts renders much of its anatomy at once clear.

The suspensory ligament is snipped all round, and the lens in its capsule removed and stained in the same way as the entire mass was. The lens substance is squeezed out through an incision in the anterior layer. The two layers of the capsule —the dark-red thick curling anterior and the delicately tinted thin posterior layer—with the adherent suspensory ligament floating in water, make one of the prettiest demonstrations of structure known to me.

The canal of Stilling is often very well seen, especially if the eye-kernel is well shaken with the picrocarmine. In doing this, very considerable violence can be used and yet no damage be done. The picrocarmine, however, enters the canal, and may penetrate apparently right up to the back of the lens. Then when the stained eye-kernel is floating in the water, the canal of Stilling may be a very conspicuous object. By the staining, also, the mouth of the canal is rendered so evident that a cannula may readily be introduced so as to inject it.

Double staining is sometimes very effective, bringing out different points according to circumstances; for instance, picro-carmine and aniline blue—first one and then the other. But I

do not need to enlarge upon these. By working at it, everyone will find out combinations for himself.

For teaching purposes I can strongly recommend the above methods.

A SIMPLE MEANS OF EXPLAINING THE NATURE OF DIPLOPIA, &c. By Professor T. P. ANDERSON STUART, M.D.

Two worsted balls are taken to represent the eye-balls, and sewn on them are circular patches of black cloth to represent the pupils. They rest in depressions in a wooden stand, so that they revolve, as it were, in their orbits. In order that they may be more stable they may be loaded with shot in their interior.

The axial rays of the cones of light rays are represented by wires sharpened at one end, so that they may pass through the pupillar space, and on through the interior of the ball to impinge upon the back of the ball—as it were upon the retina—and then through it, so that the exact position of their impact upon the retina may be shown.

Given the muscular disturbance and the position of the balls, to determine the diplopia,—thrust the wires in the direction from the real object through the pupils and balls till the retina is pierced; turn the balls with the wires still in them into the normal position. The wires now point to the positions in space to which the mind refers the objects.

Given the diplopia, to determine the position of the balls and the muscular disturbance—place the balls in the normal position thrust the wires through them as before in the direction from the apparent objects; turn the balls with the wires still in them so that the wires point to the real object. The balls are now in the required position, and from this the muscular disturbance may be inferred.

To demonstrate the "identical points" of the retina, with the balls in their normal position, thrust the wires through them in the direction from the object. The points of the retina pierced are identical.

The yellow spot should be marked on the posterior surface of the balls, and an indicator fixed into the stand opposite each yellow spot when the balls are in their normal position. Thus the demonstrator, standing behind the apparatus and facing the audience, may know accurately how the balls are directed.

A simple and always available modification of the above is afforded by two penny-pieces. Each represents a section of the ball, horizontal or vertical as the case may be. The space on the "tail" side containing the date represents a section of the cornea and anterior chamber; the date itself may be taken as the pupil. The axial rays may be lucifer matches or any such straight object, or, simplest of all, they may be imagined easily enough.

By these devices the somewhat puzzling questions of what muscles are at fault in cases of diplopia are answered more easily, and with much greater certainty in the result, than if no such means are employed. Even by men well up in the subject I have seen mistakes made constantly, and, short of mistakes being made, hesitation and doubt are often shown.

The apparatus is now made by the Cambridge Scientific Instrument Company.

A NEW MODE OF DEMONSTRATING THE RELATION OF THE TWO SIDES OF THE RETINA TO THE OUTER WORLD. By Professor T. P. ANDERSON STUART, M.D.

A HOLE about 1 mm. in diameter is made in a piece of cardboard, and behind this a piece of blue glass is fixed. Behind another such piece of wood or cardboard is fixed a piece of red glass. Of course any colours will do, so long as they are different.

When one looks through these little coloured windows, held close to the eyes, say at the sky, and the holes are widely apart, the red and blue areas are seen to correspond, as to their side, to the colours of the glasses on each side. As the windows are approximated to each other, the areas first are superposed, and then cross over to opposite sides, so that now, while the red

glass is before the right eye, the red image is referred to the left side, and similarly the blue glass before the left eye yields an image referred to the right side.

I should state that, while I had myself previously observed this crossing with the images uncoloured, yet the colouring of the images which renders the experiment so striking was accidentally discovered by Robert Grant, servitor in the Physiological Laboratory in the University of Sydney.

NOTE ON A SPEAR FLAG INDICATOR FOR MUSCLE-NERVE DEMONSTRATIONS. By Professor T. P. ANDERSON STUART, M.D.

IT is, I believe, usual to have the flag on a straw, and to pin the straw into the sole of the foot. I find it better to fix into the straw a brass pin which has been barbed by a knife. It is simply pushed into the soft structures, when it sticks quite firmly. Time and trouble both are saved.

A MODE OF DEMONSTRATING THE DEVELOPING MEMBRANES IN THE CHICK. By Professor T. P. ANDERSON STUART, M.D.

THE shell being chipped carefully all round, the egg is carefully opened under water. The ends of the shell must be pulled asunder very cautiously, so that the allantois may peel off the inner face of the shell without being torn.

The mass is now washed gently in a stream of water, so that the remains of the white and of the yolk substance may be removed. Now

1. A hypodermic needle at the end of a rubber tube, say a foot long, pushed into the cavity of the amnion or allantois enables one to inflate either of these membranes with air from the mouth, or

2. If some staining material be sucked up into the needle and tube and then thrown into the sacs they may be differentiated by colour, or

3. The washed mass may be transferred *en masse* to a staining fluid such as magenta, aniline blue, or picrocarmine, and then washed. Without further trouble the membranes are nicely seen when the mass is floated in clear water. But inflation, as above, is very effective now, and if weak magenta has been employed the blood-vessel network of the allantois is strongly stained, while the membrane in the meshes is almost unstained. The yolk-vessels are always well seen owing to the adherent yolk-particles.

If ammoniacal carmine solution, of such a strength that one cannot see through a layer one inch thick, be allowed to act two minutes, and the tissue be then washed in water just tasting of acetic acid, excellent preparations, having the merit of being more or less permanent, are obtained.

When using aniline dyes, I find it better to use tolerably strong solutions for a short time rather than weaker solutions a long time.

A METHOD BY WHICH ACCURATE DRAWINGS MAY BE MADE BY AMATEURS. By Professor T. P. Anderson Stuart, M.D.

This method is based upon photography, and will be found highly serviceable in the preparation of anatomical drawings. It consists in photographing the object, and printing in blue with ferro-cyanide developing solution.

The parts that are to be shown in the finished drawing are drawn in freehand with China ink, or even common ink, on the blue print. When this is dry the picture is passed through a solution, in water, of caustic potash or soda, one in 500 or 100, and washed with water and dried.

The alkali removes the blue printing, while the ink lines are left.

The blue print should not be too dark, otherwise delicate outlines are not easily seen, and after bleaching a brownish tint remains. In the alkali bath and in the washing some of the carbon particles of the China ink—and I prefer China ink—are washed off. This is not practically of any consequence,

for what comes off is only a mere fraction of what remains. In drying, however, an important point must be attended to. If the wet picture is simply laid out to dry the ink particles "run," so that the lines are not sharp and clear. This is avoided by laying the wet picture, immediately after washing it, between sheets of blotting-paper and drying it by the pressure of the hand for some seconds; then it should be removed and dried in any convenient way. In this way drawings, with all the accuracy of photographs, and all the clearness of woodcuts or etchings, may be produced by persons who cannot make anything like an accurate drawing or a good picture of any natural object. There is a minimum of trouble and expense.

The method constitutes, in a sense, a perfected camera lucida, and in microphotography may, I imagine, come to be very useful. Every one knows the merits and demerits of microphotography, especially of tissues,—the sharpness of outline and fulness of detail which the eye sees, but which the photograph fails to reproduce, are just what this method gives. The outline proportions are all accurately printed. The observer now can put in freehand what he sees as he sees it. If, then, a simple photograph, and another photograph taken from one treated as I have described, were printed side by side, then the reader would see the whole story—what is actually photographed side by side with the observer's interpretation.

NOTE ON THE MUSCLES OF THE RUDIMENTARY EARS—PENDANTS OF THE NECK—IN PIGS. By Professor T. P. ANDERSON STUART, M.D.

I WAS informed that many members of a litter of pigs in this country (New South Wales) were possessed of pendants of the neck such as had been described by various observers. On inquiry I found that this peculiarity was hereditary in the family, which was of the Berks breed. So strongly marked, indeed, was the hereditary nature of this "drop" that the breed is known as the "Bell Pig," and it is prized on account

of its good fattening qualities. In this case the sire had no pendants; the mother had them. Two-thirds of the litter had the pendants large and well marked, the remaining third had signs of them more or less marked.

Having obtained two specimens of them from different generations, I found that the pendants had each a core of yellow fibro-cartilage as had already been described in other animals, but in addition I found that each had a set of muscles of which I have not found any notice in the literature at my command here in Sydney.

a, The fibro-cartilage; *b*, the ridge on the cartilage giving origin to the intrinsic muscle; *c*, intrinsic muscle slips; *d*, extrinsic muscle slips.

The muscles are in two sets—an intrinsic and an extrinsic. The cartilage has a little transverse ridge near its base just before it is lost in the fibrous tissue of the neck, and from this

ridge the pale intrinsic muscle fasciculi spring, to lose themselves on the cartilage about its middle.

The extrinsic set of muscle bundles are comparatively large, and are chiefly connected with the subcutaneous muscular sheet of the region; but one slip in each case was traced down to the wall of the pharynx, in which it was lost, thus indicating throughout life the early connection of this supernumerary auricle with the pharynx and the visceral cleft. The insertion of these extrinsic slips was into the base of the cartilage and the ridge.

MAMMARY VARIATIONS *PER DEFECTUM*.

By W. Roger Williams, F.R.C.S., *Surgeon to the Western General Dispensary, late Surgical Registrar, Middlesex Hospital.*

Section I.

The development of the breast may fail at any stage of its evolution—from early embryonic life up to the climacteric period. When the morbid process sets in before the 2nd or 3rd month of intra-uterine life, there results complete suppression of the organ—*amazia.*

In animals having normally a large number of mammæ, some of them are often aborted in this way; but in human beings

Complete absence of both mammæ (Wylie).

and other bimastic animals, amazia is a very rare affection—much rarer, for instance, than polymazia.

Nearly all the cases hitherto recorded, in which the sex has been well marked, have been in females.

The deformity is frequently, but by no means invariably, associated with grave malformations *per defectum* of the adjacent chest or of the sexual organs. One or both breasts may be affected.

Complete absence of *both* mammæ is one of the very rarest congenital deformities.

Most cases have been met with in acephalous monsters, associated with deficient development of the thorax.

I know of only four instances unaccompanied by such conditions.

In the first case[1] (*see* fig.) the patient was a single woman, aged 21, who, when examined three months after giving birth to a healthy male child, was found to present no trace whatever of mammæ, areolæ, or nipples. Not a drop of milk had been secreted, so that she was unable to suckle. Menstruation set in at 15, and she had since been regular. But for the mammary deformity she was well made, and her health had been good. In answer to a letter of inquiry, Dr Wylie, her medical attendant, kindly informed me that there was no deficiency of the pectoral muscles or ribs, and that the external genitals, the teeth, hair, and other dermal appendages, were well developed.

The second case[2] occurred in the person of a woman, who one week previously had been prematurely delivered of a living child. She presented no trace of mammæ or nipples, but in the position of each of the latter was a pigmented patch of skin, the size of a sixpence.

The subject of the third[3] case was a boy 3½ years old, in whom complete absence of both mammæ from birth was associated with similar absence of hair, and an atrophic condition of the whole integument and its appendages, except that of the external genitals. The latter were well developed, except for phimosis; and presented a remarkably plump appearance, as compared with the shrivelled aspect of the rest of the body. The testes were well placed and normal. The boy's mother had suffered from *alopecia areata* from the age of 16.

Mr Hutchinson indulges in some interesting speculations as to the explanation of this remarkable case, on the basis of modern theories of heredity.

In the fourth case[4] the patient was a so-called hermaphrodite, aged 65, who had always passed for a female. On examination of the body after death, its general appearance was that of a male, and there was a tremendous beard. Both mammæ were completely absent. Menstruation had never occurred, nor was there any history of sexual desire. Further examination was

[1] Wylie, W., *Brit. Med. Jour.*, 1888, vol. ii. p. 235.

[2] Batchelor, H. T., *Brit. Med. Jour.*, 1888, vol. ii. p. 876.

[3] Hutchinson, J., *Med. Chir. Trans.*, vol. lxix. (1886), p. 473.

[4] Pilcher, *Lancet*, vol. i. (1888), p. 915.

limited to the genital organs. The clitoris was very large—quite as large as in many competent males. The corpora cavernosa were large; there was a bulb to the urethra, a rudimentary prostate, and rudimentary ejaculatores seminis. In addition there was a rudimentary uterus and vagina—the latter ending in the urethra. Nothing is said about ovaries or testes.

Complete absence of *one* breast is only a little less rare than that of both.

Several authors have stated (contrary to what happens in polymazia) that the right breast is the one more frequently affected. I am unable to support this statement; for, as will be seen below, in most of the cases collected by me the deformity was on the left side.

It is alleged sometimes to occur independently of any other deformity. Birkett[1] cites a case (Marandel's) of this kind; but, on looking up his reference,[2] I found the record so meagre and unsatisfactory that I was unable to determine whether there was associated deficiency of the pectoral muscles or not.

In the following cases unilateral amazia was correlated with malformation of the adjacent chest wall:—

1. In a woman,[3] aged 30, who died of peritonitis eight days after her confinement, there was found in place of the R. breast a shallow depression; but no trace of the nipple, areola, or gland. Beneath the skin there was nothing but a thin layer of adipose tissue. The L. breast was well developed and full of milk. The anterior parts of the 3rd and 4th ribs were absent, together with the corresponding intercostal muscles, the sternal part of the pectoralis major muscle, the whole of the pectoralis minor, and portions of the serratus magnus. The gap was closed in by tough aponeurosis. The pleura and lung were normal.

2. Here the patient was a healthy-looking girl,[4] 5 years old, whose parents also were healthy and free from any deformity. Of the R. mamma, nipple, and areola there was no trace; the skin over this region was like that of the rest of the body. The pectoralis major and minor muscles were deficient, as well as the anterior part of the 4th rib and the adjacent

[1] *Diseases of the Breast*, 1850, p. 23.
[2] *Dict. des Sci. Méd.*, t. xxx. p. 378.
[3] Froriep, *Neue Notizen*, Bd. x., 1839, s. 9.
[4] Reid, *Froriep's Neue Notizen*, No. 500, Bd. xxiii., 1842, s. 254.

intercostal muscles. At this spot, during respiratory movements, hernial protrusion of the pleura took place, the overlying skin being in close contact with the latter. The six upper ribs, except the first, were markedly bent and arched forwards on both sides, causing considerable deformity of the pelvis. The L. mamma was normal.

3.[1] In this case complete absence of the L. breast was associated with absence of the L. upper limb, which was represented only by a small conical stump at the shoulder. There was also large deficiency of the thoracic wall on this side, through which the thoracic and abdominal viscera protruded, covered only by a membranous envelope.

4.[2] A girl, aged 10, with complete absence of the L. mamma, areola, and nipple. The sternal part of the pectoralis major also wanting. The other breast normal. No heredity. The mother attributed the disease to fright during pregnancy, from having seen a woman's chest after amputation of the breast.

5.[3] In a healthy married woman, aged 22, shortly after her first confinement, complete absence of the L. breast was noticed by the medical attendant. The nipple was represented by a small pimple. The pectoral muscles of the affected side were imperfectly developed. The woman's mother first noticed the deformity three weeks after the patient's birth. She attributed it to having been frightened when pregnant by a woman who called at her house and exposed her chest, showing marks from amputation of her breast for cancer.

6.[4] A single woman, aged 21, with complete L. amazia. The pectoralis major imperfect. The patient otherwise well formed. No heredity.

Similar cases have been recorded by Lousier[5] and Schlözer,[6] but I have been unable to get access to the original memoirs.

Referring to the former of these cases, St Hilaire[7] says: "Le

[1] Förster, A., *Die Missbld. des Mensch.*, 1861, s. 105, in atlas, Taf. xi. f. 16.

[2] King, *Med. Times and Gaz.*, 1858, vol. i. p. 527.

[3] Paull, *Lancet*, 1862, vol. i. p. 648.

[4] Widmer, *Corresp. Blatt. f. Schw. Aerzte*, 1888, s. 472.

[5] *Dissert. Anat. et Physiol. sur la sécrétion du lait*, These de Paris, An. x. No. 53, p. 15.

[6] *Ueber die Angebornen Missbild. der gesam. weibl. Genitalien. Dissert. Erlangen*, 1842.

[7] *Histoire des Anomalies*, t. i. p. 710.

Docteur Lousier fait mention d'une dame qui privée d'une mamelle, transmit a sa fille le vice de conformation dont elle etait ellemême affectée." In accordance with this, almost all subsequent authors have referred to the case as an example of hereditary transmission; but, according to Puech,[1] Lousier never asserted this. All he said was, "J'ai connu une dame et une demoiselle chez les quelles la glande mammaire manquait complétement d'un côté."

In the two following cases congenital amazia was associated with total absence of the corresponding ovary. Both are reported by Scanzoni,[2] and I know of no others precisely similar, although, as I shall presently mention, there are on record many cases of micromazia associated with deficient ovarian development.

The first patient was a beggar woman, who died, aged 64, of tubercle. There was complete absence of the L. mamma, nipple, and areola, and at the necropsy no trace could be found of the L. ovary. She had been subject to amenorrhœa since the age of 27, but she had previously menstruated regularly.

The second patient was a girl, aged 18, who died of typhoid fever. In this case R. amazia was associated with complete absence of the R. ovary. She had menstruated regularly.

Absence of the breast may occasionally be caused by inflammation and injuries in the newly born. Puech[3] relates the case of a girl, aged 17, of whose L. breast there was hardly a trace, although the R. was well developed. This resulted from acute inflammation of the part at birth, followed by suppuration and the formation of a large abscess, which had to be incised.

SECTION 2.

When the defect is less complete than in the above cases, we get a very small imperfectly-developed gland, like the normal male breast, or smaller—*micromazia*. This condition, though rare, is of more frequent occurrence than any of the foregoing. The rudimentary organs are useless for lactation. Both mammæ may be affected, or only one.

[1] *Les mamelles et leurs anomalies*, p. 63.

[2] Kiwisch, *Klin. Vorträge über spec. Path. u. Therap. d. Krank. des weib. Gesch.*, Bd. iii. (1855), s. 47.

[3] *Op. cit.*, p. 90.

The deformity occurs independently, or associated with malformations of the adjacent chest or of the sexual organs, as in cases of amazia.

The following instances of micromazia of independent origin are related by Puech :[1]—

In a single woman, aged 24, there was complete absence of the projection of the bosom on both sides, while the nipples and areolæ were small and stunted. Menstruation set in at 15, but the catamenia were not regular until two years later. Her mother and sisters had well-developed breasts.

In another case it was noticed that both the breasts of a woman about to be confined were rudimentary; and they remained so after delivery, only a few drops of colostrum being secreted. Her mother had a similar deformity.

In the next case only one breast was affected. The patient was a young woman who married early, and was the mother of three children. At puberty the asymmetrical condition of the mammæ was first noticed; for while the R. attained its full size, the L. remained undeveloped. After each pregnancy the R. gave plenty of milk, but the L. none.

As examples of micromazia, associated with malformation of the adjacent chest wall, I can cite the following:—

In a single woman, aged 21, seen by Engeström,[2] all that existed of the L. breast was a small stunted papilla, and under it "un petit amas de graisse, mais si insignificant, qu'il ne forme même pas une eminence." The sternal part of the left *pectoralis major* muscle was completely absent. She was otherwise well developed.

In another case by the same author, the patient was an emaciated, phthisical woman, aged 27, who had recently been delivered of her second child. The left breast was well formed and full of milk; but the right was very small, although its nipple and areola were normal, and only a few drops of milky fluid could be expressed from it. This secretion ceased shortly afterwards. Most of the sternal part of the corresponding *pectoralis major* muscle was absent. No history of any malformation in others of her family.

[1] *Op. cit.*, p. 89. [2] *Ann. de Gyn.*, t. xxxi. (1889), p. 84.

In a similar case, seen by Ebstein,[1] the R. breast was not larger than a hemp-seed. The sternal part of the *pectoralis major* and the whole of the *pectoralis minor* muscles were wanting.

Grüber[2] saw a young lady, aged 18, in whom nearly all of the costo-sternal part of the R. *pectoralis major* muscle was wanting; and whose R. breast was represented only by a malformed nipple, surrounded by a large areola, beneath which a thin glandular *plâque* could be felt. Menstruation set in at 15, but the R. mamma never developed, although the L. attained a large size. She was otherwise well formed; but thin and phthisical.

The following cases illustrate the connection between micromazia and defective development of the generative organs. In many of the individuals thus affected the secondary sexual characters are imperfectly evolved, and there is often manifest an approach to the male type of organisation.

In a woman, aged 26, seen by De Sinetz,[3] both breasts were like those of a girl before puberty; they had no areolæ, and their nipples were hardly perceptible. The uterus and vagina were of an equally stunted, infantile type.

In a case recorded by Greenhow,[4] the patient was an unmarried servant girl, aged 22, who was very flat in the mammary regions, and on careful manipulation no trace of either gland could be felt, although she had a small stunted nipple and areola in the usual position on each side. She was of spare, girlish aspect, and had never menstruated. The pelvis and hips were small, as also was the mons veneris, on which there were but a very few hairs. The vagina was small and narrow, with a well-marked hymen. The os and cervix uteri were absent; but on rectal examination a small hard lump was detected in the position of the body of the uterus. The ovaries could not be felt. In addition, she had bifid sternum, associated with congenital malformation of the heart, the exact nature of which could not be determined. She suffered much from palpitation of the heart, cough, and dyspnœa.

Pears[5] has related the case of a dwarfed woman, aged 29,

[1] *Deutsch. Arch. f. Klin. Med.*, vi. s. 283.
[2] *Arch. f. Path. Anat.*, cvi., 1886, s. 501.
[3] *Traité de Gyn.*, 1884, p. 947.
[4] *Med. Chir. Trans.*, vol. xlvii., 1864, p. 195.
[5] *Philosophical Trans. R. S.*, Lond. 1805, p. 225.

who was only 4 feet 6 inches high. Her breasts and nipples were like those of a male. She had never menstruated. There was no hair on the pubes, nor any other of the signs of puberty. "She always expressed an aversion to young men who were too familiar with her." She had been subject to violent fits of coughing and convulsions for several years, and in one of these she died. At the necropsy the uterus was of the infantile type. "The ovaria were so indistinct as rather to show the rudiments which ought to have formed them, than any part of their natural structure." Analogous instances have been recorded by Baynham,[1] Caillot,[2] Rénauldin,[3] and others.

According to Puech,[4] the infantile condition of uterus, which generally goes with absent or rudimentary ovaries, is nearly always correlated with defective mammary development.

When, however, the uterus is really absent, the mammæ are, as a rule, unusually well developed; and in these cases the ovaries are generally normal.[5] This is just the converse of what happens in males, in whom absence of the testes is usually associated with exaggerated mammary development.

SECTION 3.

Congenital absence of the nipple—*athelia*—is much commoner than any of the foregoing anomalies.

Inasmuch as this structure is formed by upheaval of the area of skin perforated by the ducts of the nascent gland, it follows that in true athelia none of the nipple structures—skin, connective tissue, vessels, nerves, ducts, &c.—are really wanting, as Duval erroneously supposed; but we have to do simply with failure of the normal mammillary outgrowth. This condition is usually unaccompanied by any other malformation, and it generally affects both breasts. I lately saw a healthy young lady, aged 18, with marked defect of this kind, associated with eczema of the malformed parts. Her breasts were large,

[1] *London Medical Gazette*, vol. iii. 1829, p. 72.

[2] *Mém. de la Soc. Méd. d'Emulation*, Paris, t. ii. (1798), p. 270 *et seq.*

[3] *Séances de l'Acad. Roy. de Méd.*, Fev. 28, 1826.

[4] For two well recorded cases confirmatory of this view, *vide* Warren, *Surgical Observations*, Boston, 1867, p. 305.

[5] *Les ovaries et leurs anomalies*, Paris, 1873 ; see also *Op. cit.*, p. 91.

and otherwise well developed; but their nipples were completely absent, and in the place of each was a small transverse groove, surrounded by a diminutive, stunted areola. The affection dated from birth. There was no family history of any similar deformity. Menstruation was normal.

Analogous cases have been seen by Cruveilhier,[1] Davis,[2] and many others. Persons affected usually have plenty of milk during lactation, but they are nevertheless unable to suckle their children.

Like other forms of defective mammary development, athelia is sometimes found associated with defective development of the genital organs, as in the following remarkable case, related by Chambers.[6] The patient, aged 24, had the general appearance and external sexual organs of a female, including the well-developed female bust. She had always passed as a female, having been engaged as a housemaid. Both nipples were completely absent, and the place of each was occupied by a small rose-coloured spot, representing the areola. There was no hair in the pubic region. The mons veneris was ill developed. The vagina was small, and ended in a *cul-de-sac*, and there was no trace of uterus or ovaries. She had never menstruated, nor had she ever experienced menstrual molimina. In each inguinal region she had an irreducible congenital hernial tumour, each of which contained a firm circumscribed body, thought to be an ovary. These bodies were excised, but on microscopical examination after removal they proved to be testes.

In such cases as the foregoing we evidently have to do with defective nipple evolution almost *ab initio*. In consequence, we often see persistence of the depression which, in the normal course of development, marks the site where the nipple will subsequently arise. When the morbid process supervenes at a somewhat later period, then we get some of the various minor degrees of congenital mammillary imperfection which are of such frequent occurrence: thus the nipple may be small, stunted, flattened, depressed, or otherwise malformed.

Such conditions are fruitful sources of trouble during lacta-

[1] *Traité d'Anatomie Descript.*, ed. 1874, t. 2me, p. 525.
[2] *Medical Times*, vol. i., 1852, p. 250.
[3] *Trans. Obstet. Soc. Lond.*, vol. xxi. (1879), p. 256.

tion; they are, indeed, the chief causes of the acute inflammations and abscesses so common at that period.

According to Birkett,[1] out of 97 cases of acute mammary abscess, there was imperfect development of the nipple in 48, or in half the total number.

Congenital imperfection of the nipple is often found in association with neoplasms.

Of 137 consecutive cases of primary *cancer* of the female breast, I found congenital malformation of the nipple in 19 (13·8 per cent.). And of 42 cases of *adenoma*, there was similar malformation of the nipple in 10 (23·8 per cent.).

Absence of the nipple is not infrequently ascribable to traumatisms in the newly born, such as bites, burns, wounds, abscesses, ulcers, &c.

When the nipple is deficient, the areola is often stunted or absent; but it is a great rarity to find the areola absent when the nipple is well formed.

In a case of this kind described by Dr O'Flynn,[2] the patient was a healthy-looking woman, aged 30, the mother of seven children, who, when she came under observation, was pregnant for the eighth time. Her breasts were small and flaccid like those of a girl at puberty, and during her previous pregnancies they had never enlarged nor given any milk. The nipples were prominent, but neither of them had an areola. Her mother's breasts were rudimentary, and though she had eleven children, no milk was ever secreted.

SECTION 4.

At the climacteric period the breasts normally undergo atrophic changes, which usually affect the fibro-fatty as well as the glandular elements. The degree to which this involution takes place, and the age at which it sets in, are variable. Occasionally these changes begin at a very early period of life, and proceed to such a degree as to constitute veritable disease.

A well-marked instance of this affection lately came under my notice in the person of a young widow, aged 30, both of

[1] Art. "Diseases of the Breast," *Holmes' System of Surgery*, vol. iii. (1883), p. 435.

[2] *Dublin Medical Press*, vol. liv. (1865), p. 312.

whose breasts were small and flaccid, like those of a thin old woman. Before the death of her husband, two years previously, she had a well-formed bust; but since then the breasts have gradually wasted away. Her general health was good, but she was less plump than formerly. The catamenia were scanty, but regular. Shortly after the death of her husband she lost her only child.

Here grief, and suppression of the sexual function, seem to have been the determining causes.

Another somewhat similar case[1] is that of a married lady, aged twenty-four, who had noticed her breasts wasting away for four months. They were formerly well developed, and she knew of no cause for their atrophy. The general health was good, there was no organic disease, and menstruation was normal. On examination the mammæ were found very atrophied. She had been married for two years, and one year after marriage gave birth to a child, which died a few weeks afterwards of bronchitis.

In sterile women, and in those who have neglected to suckle their offspring, the mammæ often shrink to quite small proportions. Reynolds[2] has given an account of a woman, aged 21, who, having suckled her first child only for a few weeks, soon afterwards saw both her breasts completely disappear, so that not a vestige of them could be felt. Yet when she became pregnant again, they both enlarged to a fair size and gave milk; but, as she neglected to suckle, the glands soon wasted away as before—and so after each pregnancy.

There can be no doubt that the habit of weaning children does in the long run tend to defective mammary development. Disuse leads to atrophy and the result is inherited.

De Sinéty[3] says he has seen several examples of this in the women of families whose children have been weaned for several generations; and two of them, although very prolific, were unable to suckle, through failure of lacteal secretion.

Altmann[4] has recently published an interesting essay on this subject.

[1] *Lancet*, vol. i. (1884), p. 782.
[2] *Ibid.* vol. i. (1884) p. 331.
[3] *Traité de Gyn.*, p. 918.
[4] *Arch. f. Path. Anat.*, Bd. cxi. (1888), s. 318.

Atrophy of the ovaries, and morbid conditions interfering with their integrity, induce a somewhat similar condition. Thus in Potts'[1] well-known case the catamenia became suppressed, the mammæ wasted, and the body got thinner in a healthy and plump young woman, aged 23, each of whose ovaries presented as a hernial swelling at the inguinal rings, and were excised in consequence of their incapacitating the patient from work.

Other alleged causes of mammary atrophy are prolonged and excessive suckling, exhaustive illnesses, and the internal administration of iodide of potassium in large doses.

[1] *Surgical Works*, vol. iii. p. 329.

ON A DOUBLE CHICK EMBRYO. By P. CHALMERS MITCHELL, M.A. (Aberdeen), B.A. (Oxon.), F.Z.S., *Senior Demonstrator in the Morphological Laboratory, Oxford University Museum.* (PLATE VIII.)

THE double monster I am about to describe was obtained in the Embryology Class of the Oxford University Morphological Laboratory. It had been removed from the egg, and was dead before I saw it. The egg was one of a large number incubated for seventy-two hours in an artificial incubator. It was in every respect apparently normal, and until it was opened there was no sign of anything unusual. The vascular area was rather smaller than is usual in an embryo of seventy-two hours. The monster, divided for the greater part of its length, lay on a single blastoderm. The two halves each presented the appearance of an embryo of about forty to sixty hours' incubation. They lay side by side flat on the surface of the yolk, and were partly covered by a common amnion. The embryo was fixed and hardened in methyl green, with a trace of osmic; it was stained in alum carmine, dehyrated and placed in toluol.

General Description (surface view, fig. 1).

The embryo, now in a semi-transparent condition, was examined with the naked eye, and with low powers.

Amnion.—A single anterior amnion fold reached backwards over the anterior region of the embryo to the middle of the heart region. Posteriorly a single amnion fold swept over the two posterior ends of the monster. The anterior and posterior folds passed into each other, and thus enclosed an uncovered space. This was oval, and perfectly defined, and there was no trace of wrinkling or folding in its clearly cut edge. The long axis of the oval was transverse to the antero-posterior axis of the double monster. This regular disposition, and the absence of any line of junction between the parts covering the separate posterior ends of the chick, support the view[1] that the amnion is formed not by folds growing over the embryo, but by the

[1] Shore and Pickering, "Proamnion and Amnion in the Chick," *Jour. Anat. and Phys.*, xxiv.

Journ. of Anat. & Phys., April 1891.

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Fig

f.b

Fig. 3.

Fig. 5.

c

P. C. Mitchell, del

F Huth, Lith^r Edin^r

DOUBLE EMBRYO OF CHICK.

embryo sinking into the blastoderm, and in subsequent growth invaginating a blastodermic pouch fore and aft.

Body.—The outline of the body of the monster, seen partly through the amnion and partly in the uncovered space, was perfectly distinct. In the anterior region, for an area almost exactly coincident with that covered by the anterior amniotic fold, the body was a single broad mass resembling the combined anterior moieties of two ordinary embryos. From this common mass, which was in length nearly two-fifths of the entire monster, two separate bodies stretched backwards. These diverged rapidly in the uncovered space, and the two tails dipped under the posterior amnion fold at a considerable distance from each other. The monster, roughly speaking, lay within an equilateral triangle, the points of the tails being at the ends of the base, and the single anterior region at the apex.

Nervous System.—The central nervous system was visible through the greater part of its length. In the anterior undivided region, lying side by side, were two separate systems of cerebral vesicles. The mid-brain (*mbr*, *mbl*) of each side extended almost to the anterior edge of the head, and just in front of it were seen the edges of the down-turned anterior vesicles. Behind, on each side, the vesicle of the mid-brain communicated with a posterior vesicle, and that with the spinal cord continued to each posterior end.

Somites.—On each side of each nervous system were an ordinary series of mesoblastic somites.

Vascular System.—Lying in the uncovered space in the angle between the diverging bodies was the heart (*h*). This the sections subsequently showed to be double.

The vascular area was surrounded by a single perfectly normal sinus terminalis which is not drawn in the figures. Arising far back in each embryo was a pair of vitelline arteries. The vitelline arteries on the outer sides of the double monster (*i.e.*, the right vitelline artery of the right embryo (*r.v.ar.*), and the left vitelline artery of the left embryo (*l.v.a.l.*) were large and tolerably symmetrical, though not so symmetrical as the right and left vitelline arteries of a normal chick. The arteries between the diverging tails (*i.e.*, the left vitelline of the right embryo (*l.v.ar.*), and the right of the left embryo

(*r.v.al.*) were much smaller, and corresponded in size or in-disposition neither to each other nor to their corresponding arteries of the other side.

The great veins, as empirically might be expected, were more irregular than the arteries. But it was impossible to figure them or make them out with so much certainty as in the case of the arteries. On the right and on the left side of the anterior part of the embryo was a large anterior vitelline vein. These ran to the edge of the amnion, and then curving joined a main vitelline stem at each side. Posteriorly, on the inner side of the right embryo, there ran a venous trunk (*p.v.v.r.*), which curved round the tail, and gave many branches to the sinus terminalis. Posteriorly, on the outer side of the left embryo, there ran a venous trunk (*p.v.v.r.*), which curved round the tail, and gave off many branches to the sinus terminalis.

Detailed Description (fig. 1 and Sections, figs. 2–5).

Epiblast.—As may be seen in figs. 2, 3, 4, 5, the epiblast (*epbt.*) runs round the anterior end, precisely as in a normal embryo. In fig. 5 it is seen to be continuous with the epiblast of the amnion fold. There is no trace of dipping or folding between the two sets of cerebral vesicles. In the posterior halves the epiblast was perfectly normal.

Central Nervous System.—There were two complete sets of central nervous systems separate from anterior to posterior extremities. Both surface view and sections established this. In the anterior region the two sets of vesicles lay close together and nearly parallel; in the posterior region they diverged with the diverging bodies. The anterior vesicles were bent down, but the cranial flexure was not nearly so great as in a normal embryo of seventy-two hours. They were simply bent vertically downwards, and the central vesicles were not well separated. In fig. 2 to the right of the right half of the embryo a fold in the wall of the vesicle represents the constriction between the fore-brain and the cerebral bulb.

Sense-Organs.—The nasal pits on the outer sides only were developed. One is figured at *n* in fig. 2. Between the two anterior vesicles there was no dipping of the epiblast, and

therefore no epiblastic incipia for the nasal organs of the inner sides.

The eyes were of great interest; the down-turned fore-brains were turned slightly outwards, so that their anterior aspects faced away from each other. In consequence the optic regions of the inner sides of the two sets of vesicles were anterior to the optic regions, turned to the outside. On the outer side of each demi-embryo was a well-formed cup, and a lens separated from the epiblast. In fig. 4 a section showing this condition in a very typical way to the right is drawn. The plane of the sections was not quite at right angles to the long axis of the embryo, and the left of the section in fig. 4 was in front of the outer eye of the left half embryo.

As, however, the optic regions of the inner sides lay close together, the plane of the sections passed through them together. The section drawn in fig. 3 shows the greatest development of the inturned eyes. The optic vesicles were rudimentary. They were hollow vesicles, flattened dorso-ventrally, which ran towards the middle line, till they nearly met each other (fig. 3, *op.v.i.*). No optic cup was formed. As there was no inturned epiblast between the vesicles, as in the case of the nasal organs, there were no lenses formed. These rudimentary eyes were probably vestigial, not incipient. There was no room for further growth, and little possibility of the formation of secondary optic vesicles.

The ears also were noteworthy. On each outer side there was a large auditory vesicle separated from the epiblast, and beginning to show differentiation. The extreme posterior region of the vesicle to the right is shown in fig. 5 (*aud.*). A very small otic vesicle appeared on the inside of the demi-embryo to the right in the sections.

Mesoblast.—In the anterior region the mesoblast of each half-embryo was completely united, and, as in the case of the outer epiblast, there was no trace of division between the two. In the posterior region the mesoblast of the separate bodies and tails was quite normal. In fig. 5 a section is represented passing through the region where the separation of the embryos was beginning. The extra-embryonic part of the body-cavity at each side was continued for a considerable distance under the

undivided alimentary canal, towards the middle line. The somatopleure on each outer side ran on the dorsal side of this cœlomic space, round the space between the embryo and the amnion, to lie under the epiblast of the extra-embryonic region (fig. 5, *som.*). The splanchnopleure folds of each outer side ran in towards the middle line. There, probably combining with the representatives of the splanchnopleure folds of the inner sides, they met each other, and formed a large median ventral mass (fig. 5, *spl.*).

Vascular System.—The arrangement of the great blood-vessels has already been described. There were two hearts, but these were considerably modified. In the section drawn in fig 5, a large vessel at each side (*a.or.*) represents an enlarged aortic arch on the outer side of each semi-embryo. The aortas on the side, turned inwards, were in each case rudimentary, as, owing to the single alimentary canal, there was no passage for them. They were represented by long narrow slits containing a few blood-corpuscles, and nearly meeting in the middle line below. Posteriorly, the hearts of each side were normal. I have already pointed out that the vitelline arteries in the space between the halves of the double monster (fig. 1, *r.v.al.*, *l.v.ar.*) were smaller than the corresponding arteries on the outside. This is obviously correlated with the failure of the internally turned aortic arches.

Hypoblast.—In the anterior region the alimentary canal was a single tube. Posteriorly it divided in two, and in the separated parts of the embryo it was double. There were two notochords.

General Conclusions.

Category of the Monster.—Saint Hilaire[1] divides composite monsters into *autositic* monsters, where each individual is equally developed, and *parasitic* monsters, where one rudimentary individual is attached to a well-developed individual. The present instance is autositic, and falls readily into the subdivision "Syn-cephalia," where the heads are more or less confounded, but the bodies free posteriorly.

Origin.—The unusual regularity and symmetry of this double monster readily suggested the idea that it was in process of

[1] Saint Hilaire, Isodore Geoffroy, *Histoires des, Anomalies ou Traité Tératologie.*

fission, but detailed examination and comparison with recorded monsters dispelled this idea. Dareste,[1] in his classical contributions to teratology, has practically settled in the negative the question of mechanical injuries or influences producing double monsters by fission of an embryo. Moreover, there was no evidence for any mechanical lesion in this case. But progressive fission might be due to internal influences, to forces centred in the embryo.

In this case the division of the nervous system is complete, and there is produced not a pair of demi-nervous systems, but two complete nervous systems. On the other hand, the epiblast and the parts of the sense-organs derived directly from the epiblast, are not completely double. The vascular system is double, but not all the mesoblast. The notochord is double, but not all the hypoblast. To account for these facts by attributing them to internal influences would require a series of wild hypotheses. One would have to suppose the existence of separate and parallel "tendencies to division" of varying intensities at work in the different embryonic tissues. Or one would have to attribute, for instance, to a divided nervous system a capricious influence towards division over the other tissues.

The process which was going on might have been a fusion of two embryos on the same blastoderm. Allen Thomson[2] stated that when two embryos on the same blastoderm lay with similar surfaces together, fusion frequently resulted. Camille Dareste has strongly supported this view, and has added facts and arguments in favour of it. Since what has been done by surgeons recently in the grafting of adult tissues, one can hardly imagine but that embryonic tissues, in contact in any way whatever, would fuse. Such a hypothesis readily explains the present case. Two embryos on one blastoderm have come in contact. The organs and tissues along and near the point of contact have been altered. The organs and tissues not near the point of contact have been unchanged. The epiblast of the adjacent surfaces has fused. In subsequent growth the

[1] Dareste, Camille, "Sur l'origine et le mode de formation des monstres doubles," *Archives de Zoologie Expérimentale*, 1874.

[2] Thomson, Allen, "Double Monsters and their Probable Origin," London, *Edin. Med. Jour.*, 1844.

proliferating mesoblast of each side has grown together, and the septum of epiblast in between has disappeared in the anterior region. The structures that would have been formed from this epiblast were therefore absent. The appearances so readily conform to a hypothesis of fusion that in simple description it was difficult to avoid terms directly implying fusion. Irregularities, such as the presence of an auditory vesicle on one interior side, were due to the fusion not being absolutely symmetrical.

To account for the presence of two embryos on a single blastoderm is another matter. The egg in this case was to all appearance perfectly normal, and it was incubated in an artificial incubator with a batch of eggs that were perfectly successful. Where there are two blastoderms on an egg, it may be possible to assume that two ovarian ova are in some way fused. In cases like the present there seems no reason to assume that the double monster is not the product of a single ovarian ovum, and therefore of a single germinal vesicle. It is known that segmentation in the hen's egg occurs in a constant way. The first plan of segmentation is at right angles to the long axis of the egg. The egg is a composite structure, and, as is well known, it is only the yolk that represents the ovarian ovum, and therefore the cell. The yolk is usually described as a regular sphere. I have carefully hardened eggs in different ways, and have measured the horizontal and vertical axis of the yolk. In every case I found that the axis parallel with the long axis of the whole egg was the longest axis. It is the case then that, in normal segmentation of the hen's egg, the first plane of segmentation is at right angles to the long axis of the yolk—to the long axis of that part of the egg that represents the ovarian cell. This is in conformity with the general case formulated by the Hertwigs[1] that the plane of a division in a cell crosses at right angles that axis of the cell that passes through the greatest bulk of non-active protoplasm. In the chick, this first axis coincides with the ultimate long axis of the embryo. It may be assumed that the first segmentation divides the active protoplasm into protoplasm to form the right and left halves of the embryo. Now, if the first plane of segmentation were along the

[1] Hertwig, R. u. O., *Untersuchungen zur Morphologie und Physiologie der Zellen*, Jena, 1886.

long axis of the cell—not across it,—other things being equal, the active protoplasm would be divided into two halves, each capable of producing a right and left, and consequently two embryos and not one would result. Subsequent conditions would determine whether the two embryos developed completely and the egg produced identical twins, or whether they sooner or later fused and produced a more or less divided monster. It would be of great interest to have observations on the direction of the axis of a double monster. On the above theory it might very well happen that the long axis of a double monster would be parallel, not at right angles to the long axis of the ovum. In the present case I did not see the embryo till it had been removed from the egg, and I made no observation of this point.

The stage of development to which this embryo had attained is noteworthy. Even while remembering that the time relationships are very variable in chick development one remarks that the degree of development attained by this double chick is very far behind the degree of development usually attained in seventy-two hours. The chief factor in this retardation probably is the increased bulk of elaborated protoplasm required.

To build up each stage of a double or nearly double embryo from a single ovum, double or nearly double the specialised protoplasm and nuclear matter required for a single embryo of the same stage has to be elaborated, and to produce this elaboration there is only the nuclear substance of a single ovum and spermatozoon, the yolk of a single egg and the absorbing surface of a single egg.

An avian, unlike a mammalian embryo, has only a limited source of organic nutrition, and the probable fate of a monster like this double embryo would be death, due to exhaustion of food supply before maturity had been reached.

EXPLANATION OF PLATE VIII.

am, Amnion.
epbt, Epiblast.
mbt, Mesoblast.
hbt, Hypoblast.
som, Somatopleure.
spl, Splanchnopleure.
bc, Body cavity.
mb.r, II. Cerebral vesicle of right embryo.
hb.r, III. Cerebral vesicle of right embryo.

mb.l, II. Cerebral vesicle of left embryo.
hb.l, III. Cerebral vesicle of left embryo.
fb, Fore-brain.
hb, Hind-brain.
mb, Mid-brain.
n, Nasal pit.
op.v.i, Optic vesicles of inner side.
op.v.r, Optic vesicles of outer side to the right.
l, Lens.
aud, Auditory vesicle.
h, Part of the hearts lying in the space between the diverging bodies.
o.aor, Outer aortic arch.
aor, Rudimentary inner aortic arches.
r.v.ar, Right vitelline artery of right embryo.
l.v.ar, Left vitelline artery of right embryo.
r.v.al, Right vitelline artery of left embryo.
l.v.ar, Left vitelline artery of left embryo.
a.v.v.r, Anterior branch of vitelline vein on right side.
a.v.v.l, Anterior branch of vitelline vein on left side.
p.v.v.r, Posterior branch of vitelline vein of right embryo.
p.v.v.l, Posterior branch of vitelline vein of left embryo.
n.c, Notochord.
al.can, Joint alimentary canal.

Fig. 1. Dorsal view of monster in a semi-transparent condition.

Figs. 2, 3, 4, 5. Selected sections from a series cut vertically through the anterior end of the embryo. The plane of the sections was slightly inclined to the longitudinal axis.

Fig. 2. Through the fore-brain of the right side, and on the left through the fore-brain and nasal pit below; above through the anterior end of the mid-brain.

Fig. 3. A little posterior to fig. 2; through the mid-brain of each side above, and through the fore-brain below; passes through the vestigeal optic vesicles of the inner sides.

Fig. 4. Posterior to fig. 3; through the lateral eye on the right side of the figure, in front of the lateral eye on the left.

Fig. 5. Posterior to fig. 4; through the hind-brain on each side; through the anterior end of both notochords, and through the posterior end of the auditory vesicle to the right, and through the unpaired anterior section of the alimentary canal, and through the aortic arches.

AN ABNORMAL ARRANGEMENT OF THE RIGHT SUBCLAVIAN ARTERY IN A RABBIT. By W. RAMSAY SMITH, B.Sc.

SOME time ago, on making an injection of the arterial system of a large, full-grown, male rabbit, and dissecting out the vessels of the anterior extremity, I found that the subclavian artery on the right side was abnormal in its origin and course. Intending to keep the specimen merely as a permanent preparation of the arterial system, I had allowed it to stand aside for some time before examining it carefully, and unfortunately the parts were in such a condition that the relations of some of the adjoining structures to the subclavian artery could not be made out with certainty. The preparation, however, shows very well the following peculiarities:—

1. There is no innominate artery, the four large vessels all arising independently from the arch of the aorta.

2. The right common carotid artery is given off from the arch of the aorta at the point where the innominate artery usually arises.

3. The left common carotid artery is given off from the arch immediately beyond the right.

4. The left subclavian artery, which is of smaller size than usual, arises from the superior aspect of the arch of the aorta in very much its normal position.

5. The right subclavian artery arises from the back (dorsal aspect) of the arch of the aorta, just where the vessel begins to descend, and passes behind the œsophagus and trachea to assume its proper position as it approaches the first rib. All its branches have their usual origin and course.

6. The left subclavian vein follows the normal course.

In rabbits the origin of the vessels from the arch of the aorta is subject to considerable variation. I believe the most common arrangement is that shown in fig. 2, which I give for comparison with the abnormal arrangement I have just described, shown in fig. 1.

This abnormality of the right subclavian artery passing behind the œsophagus and trachea is relatively by no means uncommon in the human subject (see *Quain's Anatomy*, 9th ed., vol. i. p. 357, where the arrangement is figured and explained and references are given); but so far as I am aware, it has not been reported as occurring in the rabbit. As this case is the only one I have found in a careful examination of about 700 specimens, I think the condition must be somewhat rare.

Fig. 1. Fig. 2.

Fig. 1. Abnormal arrangement of the right subclavian artery.
Fig. 2. Normal arrangement of the arteries arising from the arch of the aorta.

c^1, c^2, right and left common carotid arteries; s^1, s^2, right and left subclavian arteries; a, aorta; i, innominate artery; v^1, v^2, superior (right) and inferior venæ cavæ; t, trachea.

HUMAN CEREBRUM WITH A REMARKABLY MODIFIED FRONTO-PARIETAL LOBE. By PROFESSOR SIR WM. TURNER, M.B., LL.D., D.C.L., F.R.S.[1]

IN September 1881, I received from my friend and former pupil Dr Herbert C. Major, at that time the medical head of the West Riding Asylum, the right hemisphere of a human cerebrum, which possessed a very remarkable arrangement of the fronto-parietal convolutions.

Before I describe the characters of the specimen, I shall give some account of the man from whom the brain was obtained from notes kindly supplied through Dr Major, by Mr W. Bevan Lewis, the present medical head of the Asylum.

History.—Joseph Braine was admitted to the West Riding Asylum when 21 years of age. He was a confirmed epileptic, especially dangerous and violent towards children. His father said that he was like other boys until he had his first fit when 15 years old. At first the fits were occasional, but latterly several occurred daily for a week or ten days and then ceasing for a fortnight again frequently recurred. He had no suicidal tendency; and there was no history of injury having been received. His state on admission was as follows:—Expression dazed, great dementia and loss of memory, but he knew that he had come to an asylum. He does not know the number of days in the week, or the names of the days. He cannot multiply. He said that the fits began in the left wrist; the spot was rather indefinite, but seemed to be a little in advance of the wrist, and on the dorsal side of the hand, in a line between the fore and middle fingers. He was fairly nourished; head small and long; face long and features large; hair light; eyes grey; pupils unequal, left the larger, both active; tongue tremulous, but protruded straight; teeth fairly good; palate high and arched; chest misshapen; locomotion rather unsteady. During his residence in the asylum he was very irritable, vicious, and pugnacious, especially prior to a fit. The fits were frequent, but their characters were not noted. He died of phthisis, æt. 26 years.

Post-mortem.—The skull cap was long and narrow; the bones generally somewhat thin, but of the usual density. The brain was generally very pale. The entire brain weighed 1107 grammes (39¾ oz.); right hemisphere, 437 grammes (15 oz. 6·6 dr.); left hemisphere, 530 grammes (18 oz. 11 dr.); cerebellum, 127 grammes

[1] Communicated to the Anatomical Society, February 23, 1891.

(4 oz. 7·6 dr.); pons, 14 grammes (8 dr.); medulla oblongata, 6 grammes (3·3 dr.).

Left hemisphere showed on the cranial surface a slight degree of wasting in the upper frontal and parietal regions, but with this exception no special abnormality was noted, for the convolutions had a normal development and arrangement. When sliced into no unusual appearance was seen and no undue firmness.

Right half of the brain showed the crus cerebri and the anterior pyramid of the medulla to be distinctly smaller than the left and firmer than natural. The corpus striatum and optic thalamus were apparently smaller than on the left side. The pia mater, covering an extensive area, where the convolutions on the cranial surface were modified, was opaque and thickened, but elsewhere it was apparently normal. When the membrane was stripped off the altered convolutions they were seen to be increased in consistency, "evidently by a process of sclerosis."

The record of the *post-mortem* examination also includes a short description of the area of malformation, which it is unnecessary to reproduce, as I shall now give a fuller description of the right hemisphere as it came into my possession. I may say that no other part of the brain was sent to me.

The RIGHT HEMISPHERE, after having been for nine years in spirit, measured 137 mm. in the greatest antero-posterior diameter, and 103 mm. in the greatest vertical diameter. It weighed 312 grammes (11 oz.) having lost 125 grammes since it was immersed in spirit. One of the first appearances to attract one's attention, was the wide patency and shallowness of the Sylvian fissure. Its length from its posterior end to the anterior end of the orbital operculum was 70 mm., and it extended backwards and upwards on the cranial surface of the hemisphere.

The island of Reil, to a large extent exposed between the lips of the Sylvian fissure, was 48 mm. in antero-posterior diameter and 24 mm. in vertical diameter. Its upper and anterior part was bounded by a distinct sulcus insulæ, but inferiorly it blended with the deeper surface of the superior temporo-sphenoidal convolution. It was marked by shallow furrows, so that it had an imperfectly convoluted appearance. One of these furrows, somewhat deeper than the the rest, extended obliquely upwards and backwards and probably represented the *sulcus centralis insulæ* of Guldberg and Eberstaller; for it imperfectly divided the insula into a smaller anterior segment—*insula anterior*, and a larger posterior segment—

insula posterior. Both in front of and behind this fissure a short oblique fissure was situated.

The lower boundary of the Sylvian fissure was formed by the superior temporo-sphenoidal convolution, which formed a distinct operculum and presented no special peculiarity either in appearance or arrangement. The superior or fronto-parietal boundary was so greatly modified that it will be necessary to pay especial attention to the convolutions in the fronto-parietal part of the brain.

An examination of the cranial surface of the fronto-parietal region showed the absence of the ascending frontal and parietal, or the central convolutions; of the fissure of Rolando, the præcentral fissure, and the anterior or ascending part of the intraparietal fissure. The convolutions of the frontal lobe were continued directly backwards into the parietal region, and these again were prolonged partly into the convolutions of the occipital lobe and partly into those of the temporo-sphenoidal lobe. The arrangement was such that one might describe it as consisting generally of a series of antero-posterior convolutions arranged in tiers, having an arcuate disposition in relation to the Sylvian fissure. But a more particular description of the convolutions is required.

If we begin with the orbital surface of the frontal lobe we find that it possessed a slender gyrus rectus, bounded externally by an olfactory fissure. The olfactory bulb and peduncle had not been preserved, but the external root was distinct, and passed backwards and outwards in relation to the locus perforatus anticus, to join the lobus hippocampi. External to the olfactory fissure was an internal orbital gyrus, which was bounded externally by a radiated intra-orbital fissure, which separated the internal from an external orbital gyrus. Behind the intra-orbital fissure was a distinct convolution which bounded the Sylvian fissure anteriorly and formed the orbital division of the fronto-orbital operculum.[1] The orbital surface of the frontal lobe possessed therefore a normal appearance.

The orbital operculum was continued backwards into the

[1] See for the more precise nomenclature of this region, Eberstaller, *Das Stirnhirn*, Wien und Leipzig, 1890; D. J. Cunningham, "The Sylvian Fissure," *Jour. of Anat. and Phys.*, January 1891.

inferior frontal convolution. This convolution was wedge-shaped in form. At its base, which was anterior, it was continuous with both the orbital operculum and the external orbital gyrus. It was prolonged backwards for 53 mm., and terminated behind as an attenuated convolution, which formed the upper boundary of the sulcus insulæ, and of the shallow dilated Sylvian fissure in the anterior two-thirds of its extent. Near the anterior end of the island of Reil, the inferior frontal convolution was indented by a fissure 10 mm. long, running almost horizontally forwards, which apparently represented the anterior horizontal limb of the Sylvian fissure. The part of the convolution behind this fissure was very attenuated and ended almost in a point. It possessed neither a diagonal fissure, nor an anterior limb to the Sylvian fissure, and consequently there was no trace of a differentiation of the inferior frontal convolution into the basilar, ascending and triangular portions which Eberstaller has described as normally present in this convolution.

The middle frontal convolution was continued backwards and upwards from the external orbital gyrus, and was separated by an intermediate fissure from both the inferior and superior frontal convolutions. At first it consisted of a single tier; but as it passed backwards it became divided and subdivided by fissures running antero-posteriorly, until at length four tiers of convolutions resulted from this division. The highest of these tiers reached the great mesial longitudinal fissure in the region of the præcuneate lobule, behind the end of the superior frontal convolution, and apparently represented there the postero-parietal convolution. Posteriorly it bent around the outer end of the parieto-occipital fissure, as the first annectant or bridging convolution, and was continued into the upper convolution of the occipital lobe. Before it reached the occipital lobe it underwent a partial subdivision by a short antero-posterior fissure. The second tier, separated from the first and third by distinct fissures, was prolonged backwards and downwards behind the posterior end of the parallel fissure, mainly into the second temporo-sphenoidal convolution, though it also sent an offshoot into the first temporo-sphenoidal convolution. The third tier commenced well forwards above the inferior frontal convolution, and at first was separated from the Sylvian fissure by both that

convolution and the fourth tier; but further back it formed the upper boundary of the Sylvian fissure, and, bending behind its posterior end, it became continuous with the superior temporo-sphenoidal convolution. The fourth tier was only 32 mm. long, and might perhaps be regarded as only an offshoot of the third tier; it was at first interposed between that tier and the inferior frontal convolution, but for a very short distance behind the attenuated end of the latter it reached the Sylvian fissure, and fused with the under surface of the convolution of the third tier. The posterior parts of the first, second, and third tiers were in the parietal region, and represented the modified convolutions of the parietal lobe.

h.ri.

F.m.

in.

a.h.

Fig. 1.—*F.s.*, superior; *F.m.*, middle; *F.in.*, inferior frontal convolution; *op.*, orbital operculum; *ol.*, olfactory fissure; *a.h.*, anterior horizontal limb of Sylvian fissure; *s.i.*, sulcus insulæ; *p.p.*, superior postero-parietal convolution; *an.*, angular convolution; *p.o.*, parieto-occipital fissure; *b.i.*, superior bridging convolution; *b.ii.*, second bridging convolution.

The superior frontal convolution was continuous in front with the internal orbital gyrus. It ascended on the cranial surface of the hemisphere as the marginal convolution of the mesial longitudinal fissure, and passed back as far as the line where the calloso-marginal fissure was prolonged upwards to the

margin of the hemisphere. The anterior two-thirds of this convolution were normal in shape and appearance, but in its posterior third it lost rapidly in breadth, so that immediately in front of the upward prolongation of the calloso-marginal fissure it came almost to a point. The narrow posterior end from its position apparently represented the para-central lobule, which corresponds in the normal hemisphere with the upper ends of the ascending frontal and parietal convolutions.

The mid-frontal convolution, which may more appropriately be called fronto-parietal, and the inferior frontal convolution were much altered in appearance on the free surface, which, instead of being smooth, was marked by numerous shallow furrows; the convolutions, moreover, were twisted and indented, so that they had a distinctively crenulated aspect. I have no doubt that this is the part of the hemisphere which is said in the notes of the *post-mortem* examination to have been in a state of sclerosis.

The occipital lobe was differentiated by the parieto-occipital fissure, the upper end of which, 14 mm. long, was bounded by the first bridging gyrus as already described; but below this gyrus a deep fissure extended as far down as the lower border of the hemisphere, which on a superficial inspection seemed to cut off the occipital from the parietal and temporo-sphenoidal lobes as sharply as in the hemisphere of an ape. On opening up this fissure, however, an annectant convolution, which from its position may be called the second bridging gyrus, was seen to pass from the deeper surface of the posterior end of the second tier of the great mid-fronto-parietal convolution, into the deeper surface of the middle part of the occipital lobe, immediately behind the parieto-occipital fissure. The part of the second tier from which the second bridging convolution proceeded corresponded therefore to the angular gyrus in a normal brain. A third bridging convolution was also concealed lower down in the same fissure, and connected the combined posterior ends of the second and third temporo-sphenoidal convolutions with the lowest convolution of the occipital lobe. It is rare to find in the normal human brain the second bridging convolution concealed in the parieto-occipital fissure, but I have occasionally seen the third and fourth convolutions quite hidden. The dis-

position and appearance of the convolutions of the occipital lobe itself presented no special anomaly.

The temporo-sphenoidal lobe consisted as usual of three convolutions. The parallel fissure was deep, and distinctly differentiated the superior from the middle convolutions; but the continuity of the fissure between the middle and inferior convolutions of this lobe was interrupted, as is not unfrequent, by two secondary bridging convolutions. The surface of the convolutions of this lobe was normal in appearance.

The convolutions of the mesial and tentorial surfaces of the right hemisphere possessed no abnormality requiring special description, but some points in the anatomy of these regions may be noted. The corpus callosum was 61 mm. long and 12 mm. in its greatest thickness. The genu was not so abrupt as usual, for its curve extended for a greater distance upwards and backwards. The gyrus fornicatus was well seen in its callosal, hippocampal and uncinate divisions, the last named of which was well developed. The calloso-marginal (splenial) fissure was bridged by a slender gyrus about its middle; posteriorly it reached the margin of the hemisphere at the spot already noted. The parieto-occipital, calcarine and collateral fissures, with the convolutions bounding them, were normal. The collateral fissure was not interrupted by a bridging convolution.

From this description it will be seen that a large part of the convoluted surface of the hemisphere was normal both in appearance and arrangement; but on the cranial or outer surface of the fronto-parietal region both the appearance and arrangement were greatly altered. As already stated the convolutions and fissures characteristic of the region of continuity of the frontal with the parietal lobes were not developed. In the anterior part of the frontal lobe the superior, middle and inferior convolutions presented the customary arrangement into three tiers. Although the inferior frontal convolution ended a short distance behind the anterior horizontal limb of the Sylvian fissure, five tiers of convolutions were visible immediately behind it, viz., the four subdivisions of the mid-fronto-parietal and the superior frontal. Even in the plane above the posterior end of the Sylvian fissure, where the supero-frontal convolution had come to an end, the division of the mid-

fronto-parietal convolution gave four tiers. Of these, the highest tier, continuous with the occipital lobe through the first bridging convolution, was apparently the postero-superior parietal convolution; whilst the tiers situated between it and the Sylvian fissure apparently represented much subdivided and very tortuous angular and supra-marginal convolutions. The fissure between the postero-superior parietal convolution and the tier immediately below it, apparently represented the horizontal limb of the intra-parietal fissure. Although the two central convolutions were not differentiated, yet a certain area in the tiers of the mid-fronto-parietal convolution doubtless represented them in their histological structure and physiological properties. The imperfect development of the posterior part of the inferior frontal convolution, and the modification in the mid-fronto-parietal convolution led to the non-development of the fronto-parietal operculum, so that the great trunk of the Sylvian fissure was widely patent.

A few words may now be said as to the probable cause of the production of the interesting modification in the arrangement of the convolutions, and the period in the development of the hemisphere when the divergence from the normal plan of evolution took place. It will be observed that, notwithstanding the arrangement of certain of the convolutions in tiers, which to some extent recalled the disposition in the cetacean or the more complex carnivorous brains, yet the hemisphere possessed normal human characters in the antero-frontal, the occipital and the temporo-sphenoidal regions, as well as on the mesial and tentorial surfaces. The modifications in the arrangement of the convolutions were not general, therefore, but were limited to the parietal lobe and to its plane of continuity with the frontal lobe, and were especially marked where the fissure of Rolando and the ascending frontal and parietal convolutions should have been.

The study of the development of the human cerebrum has proved that the fissure of Rolando begins to appear in the latter part of the fifth, or in the beginning of the sixth month, and that it originally consists of a superior and an inferior segment which in the course of time become continuous with each other.[1]

[1] See Professor D. J. Cunningham's paper in *Jour. of Anat. and Phys.*, vol. xxv. p. 6, Oct. 1890.

The fissure of Rolando may or may not differentiate before the præcentral fissure; but it usually, if not invariably, precedes the formation of the intra-parietal fissure and of the convolutions of the frontal and parietal lobes. The special modification in development which this brain exhibits had apparently taken place about the fifth or sixth months, so as to stop the formation of the Rolandic and præcentral fissures with their characteristic convolutions, but not to prevent the formation of a series of antero-posterior convolutions in the fronto-parietal regions. From the notes made at the *post-mortem* examination, it is evident that the pia mater in the region under consideration was altered in its characters from disease. It is not unlikely that a local inflammation of the pia mater had, from some cause or other with which we are not acquainted, occurred in the fœtus at the time when the evolution of the fissure of Rolando and the contiguous parts of the right hemisphere ought to have taken place. An obstruction had thus arisen to the normal evolution of the cerebral cortex, which, though sufficient to prevent the production of certain vertical transverse fissures and convolutions, permitted an antero-posterior arcuate arrangement to be substituted.

In the brief notes which had been recorded of the condition of the patient during life, no reference is made to any affection of the motor apparatus, the cortical centres of which are associated with the two ascending convolutions and the inferior frontal convolution; his demented condition probably interfered with the making of accurate observations on this matter. It is probable that, notwithstanding the modification in the form and direction of the convolutions, the usual cortical centres were present, though their morphological position was altered. It is interesting, however, to note that the patient associated the starting-point of his epileptic fits with the left wrist and dorsum of the hand; a region which has the cortical centre in the convolutions which bound the fissure of Rolando about midway between the Sylvian and the mesial longitudinal fissures.

The local change consisted in something more than a modification in the arrangement of the convolutions. They were affected with sclerosis and were to some extent atrophied. The

wasting had occasioned such a diminution in weight that the right hemisphere was 93 grammes lighter than the left. The general diminution in brain weight was also very marked. Instead of approximating to 1400 grammes (49 oz. 6 dr.), which is about the mean weight of a male European aged 26 years, it was only about .40 oz., which is the mean weight of a boy about 5 years old. The physical and mental feebleness in this case are probably not due to the modified arrangement of the convolutions, but to the sclerosis, atrophy, and diminished brain-weight.

The arrangement of convolutions found in this human hemisphere is undoubtedly very rare. Some weeks ago I received from Professor Carlo Giacomini, of Turin, a copy of his elaborate work on the Brain in Microcephaly,[1] and in it I found a description, with figures, of a case which presented many points in common with that above described. This case is that of Redoglia Silvio, an epileptic and imbecile, who died in 1884, æt. 14. The cadaver weighed 25 kilogrammes, and the height was 1·38 metre. The encephalon with its membranes weighed 765 grammes; the left hemisphere 353 gr., and the right hemisphere 243 gr. The convolutions of the left hemisphere presented no special peculiarity in arrangement; but those of the right hemisphere, were greatly modified. Thus the Sylvian fissure was widely patent; the superior temporo-sphenoidal convolution and the orbital operculum were well marked. There was no trace of a fissure of Rolando with its limiting convolutions, or of a præcentral fissure, and the frontal convolutions, at least the superior and middle, were continuous with those of the parietal lobe, which ran antero-posteriorly, though a superficial depression tended at one spot to interrupt the continuity. The inferior frontal was wedge-shaped, and came to an attenuated end posteriorly, as in my specimen. The subdivision of the mid-fronto-parietal convolution into tiers was strikingly marked, as was also its continuity with the superior and middle temporo-sphenoidal convolutions. The parieto-occipital fissure was distinct at and near the margin of the hemisphere, but not, as in my specimen, in the lower two-thirds of the cranial surface of

[1] *I Cervelli dei Microcefali*, Torino, 1890, osservazione xiii. p. 151, plates viii., xiii.

the hemisphere. On the mesial surface it was separated from the calcarine fissure by two bridging convolutions, which were situated superficially.

The corpus callosum was 55 mm. long; the right hemisphere was 132 mm. long and 88 high; the left hemisphere was 138 mm. long and 98 high. The breadth of the cerebellum was 95 mm.

It is obvious from Professor Giacomini's figure of the outer surface of the right hemisphere, that the convolutions in the modified area had a crenulated appearance, similar to what I have described in my specimen. In both brains there can, I think, be little doubt that the starting-point of the mal-development was due to pathological changes occurring either in the hemisphere itself or in the pia matral envelope, at or near the time when the fissure of Rolando was about to differentiate. Giacomini's specimen weighed 442 grammes less than mine, so that the entire brain was only 26 oz. 15 dr. It was therefore distinctly microcephalic. As my specimen was 10 oz. below the normal weight, it may be grouped also amongst the microcephali.

Giacomini classifies those cases in which the microcephalic condition is associated with pathological changes as pseudo-microcephali, the encephalic atrophy and modified convolutions being secondary to the morbid process. He puts Redoglia's case into this group. He quotes a case recorded by Gustav Retzius (Stockholm, 1878) in which there was no trace of a fissure of Rolando, and the fissures and convolutions were far removed from the normal. He also refers to a case described by Mierjejewski (*Congrès international des Sciences méd.*, Genève, 1877), in which the fissure of Rolando was wanting.

THE DEVELOPMENT OF THE GYRI AND SULCI ON THE SURFACE OF THE ISLAND OF REIL OF THE HUMAN BRAIN.[1] By D. J. CUNNINGHAM, M.D., *Professor of Anatomy, University of Dublin.*

THE admirable description of the gyri and sulci on the surface of the island of Reil, which has been given by Eberstaller,[2] leaves little to be desired in so far as the adult brain is concerned. He points out that the insula is divided into an anterior and a posterior part by a sulcus which lies in the same plane and presents the same direction as the fissure of Rolando. This furrow had previously been noted by Hefftler[3] and Guldberg,[4] and the latter author has suggested for it the very appropriate name of sulcus centralis insulæ, which indicates not only its central position in the island of Reil, but also its relation to the central fissure on the outer face of the hemisphere mantle. The portions of the island of Reil which lie in front of and behind this sulcus, Eberstaller has termed the insula anterior and the insula posterior.

It will be necessary for me to state briefly the further points in the anatomy of the island of Reil which have been elucidated by Eberstaller, in order that I may be able to render intelligible the few additions to his description which I wish to make, as well as the facts relating to the development of the convolutions and sulci of the insula which I have observed. According to Eberstaller the anterior insula is connected entirely with the frontal lobe, whilst the posterior insula is exclusively connected with the parietal and temporal lobes.

The insula anterior presents three gyri which unite below to

[1] This is an abstract of a portion of a Memoir on the Cerebral Surface, which is in course of preparation. Cunningham Memoir, No. VII., *R.I.A.*

[2] "Zur Anatomie und Morphologie der Insula Reilii," *Anatomischer Anzeiger*, No. 24, 15th November 1887, p. 739.

[3] *Vide* a Report upon Dr Hefftler's Inaugural Dissertation upon "Die Grosshirnwindungen des Menschen und deren Bezeichungen zum Schädeldach," by Prof. Landzert, in the *Archiv. für Anthropologie*, Band x., 1878.

[4] "Zur Morphologie der Insula Reilii," *Anatomischer Anzeiger*, No. 21, 1st October 1887, p. 659.

form the pole of the island of Reil, whilst above they are separated from each other by two sulci. These three convolutions Eberstaller names from before backwards, the gyrus brevis primus, the gyrus brevis secundus, and the gyrus brevis tertius. The gyrus primus and the gyrus tertius are, as a rule, strongly marked, whilst the intermediate one is more weakly developed. It appears to me that a better name for the gyrus tertius would be the gyrus centralis anterior, seeing that this term would indicate its position with reference to the central sulcus, and at the same time show its relation to the anterior central (or ascending frontal) convolution on the outer face of the hemisphere. The gyrus tertius is continued downwards on the surface of the island of Reil very much in the direction of the ascending frontal convolution, and its upper end lies concealed under that part of the fronto-parietal operculum which is formed by this convolution of the frontal lobe. Of the two sulci which separate the three gyri breves, the anterior, termed by Eberstaller the sulcus anterior, is always well expressed, but it rarely reaches so low as the pole of the fore island. For reasons which will become more apparent afterwards, the term sulcus præcentralis Reilii, proposed by Guldberg, would be more appropriate for this sulcus. As a rule, the second sulcus is often little more than a shallow depression of a triangular form which intervenes between the upper portions of the gyrus secundus and the gyrus tertius.

But Eberstaller describes two additional gyri in connection with the insula anterior. These he terms the gyrus transversus and gyrus accessorius. The gyrus transversus extends forwards from the pole of the island, and is of the nature of an annectant gyrus, seeing that it connects the lower part of the insula anterior with the under or orbital face of the frontal lobe. When superficial, as indeed it very frequently is, it is interposed as a barrier between the lower end of the furrow which limits the island of Reil in front and the vallecula Sylvii. Sometimes however, it is depressed and deep, and then a superficial connection occurs between the anterior limiting furrow of the insula and the vallecula.

The gyrus accessorius is placed on the outer side of the gyrus transversus. It stretches forwards from the fore part of the gyrus brevis primus, and lies under cover of the orbital operculum at

a lower level than the anterior horizontal limb of the Sylvian fissure. As Eberstaller has pointed out, this small convolution is frequently carried right across the anterior limiting sulcus of the insula, and becomes continuous with a corresponding gyrus on the deep surface of the outer part of the orbital operculum. Eberstaller lays great stress upon the connection which he believes to exist between the gyrus accessorius and the external orbital limb of the Sylvian fissure. He states that, in cases where this limb is absent, there is a corresponding furrow on the deep surface of the orbital operculum which exactly overlies the gyrus accessorius. I would point out, however, that this furrow should be considered as being more in relation to the sulcus on the surface of the insula which bounds the gyrus accessorius on its mesial aspect. When the gyrus in question is carried across the anterior limiting sulcus it joins that part of the orbital operculum which lies between the anterior horizontal and the external orbital limbs of the Sylvian fissure.

The insula posterior is divided into two convolutions, which lie one in front of the other, by a well-marked sulcus, which may be called the sulcus postcentralis Reilii. This furrow extends upwards and backwards into the posterior part of the superior limiting furrow of the island of Reil, but, in front and below, the two convolutions unite beyond it. For the anterior convolution, which is covered at its upper end by that part of the fronto-parietal operculum which is formed by the base of the ascending parietal convolution, Eberstaller employs the term suggested by Giacomini, viz., the gyrus longus; but it would be much better named the posterior central gyrus,—a term which would not only indicate its position with reference to the sulcus centralis, but also its relations to the posterior central convolution on the outer face of the hemisphere. The posterior convolution of the hinder insula Eberstaller terms the gyrus posterior secundus. The upper end of this convolution stands in relation to the fore part of the supramarginal convolution of the parietal lobe.

As we have seen, the two gyri of the posterior insula unite below the postcentral sulcus, and are then continued onwards by a common stem. This is separated from the pole of the anterior insula by the sulcus centralis, and Eberstaller considers that it is carried on to the deep surface of the extremity

of the temporal lobe, on which, he states, it can be traced to the temporal pole. Certainly in the adult the condition of affairs presents this appearance, but we shall see later on that a study of the development of the parts appears to indicate that the connection is not with the temporal lobe, but with the great limbic lobe.

There is thus a very close correspondence between the convolutions and sulci on the surface of the island of Reil and those on the lateral surface of the hemisphere. The two central convolutions (*i.e.*, gyrus brevis tertius and gyrus longus of Eberstaller) correspond with the two central convolutions (ascending frontal and ascending parietal), and the three fissures, viz., the sulcus præcentralis Reilii, the sulcus centralis Reilii, and the sulcus postcentralis Reilii, are in every respect comparable with the sulcus præcentralis inferior, the fissure of Rolando, and the vertical limb of the intraparietal fissure on the surface of the mantle. It is true that we cannot regard these corresponding convolutions and sulci as being directly continuous with each other, but still, in many cases, something which approaches very nearly to continuity occurs. Thus it is well known that the inferior præcentral sulcus, the fissure of Rolando, and the intraparietal sulcus are not infrequently carried downwards, so as to cut into the fronto-parietal operculum, and open into the Sylvian fissure. Eberstaller has pointed out that when this occurs in the case of the fissure of Rolando the condition is brought about by the extension upwards round the lower margin of the operculum of a small variable furrow, which he terms the inferior transverse sulcus. This undoubtedly belongs to the same system as the fissure of Rolando and the sulcus centralis Reilii—in other words, it is to be regarded as the connecting link. The extension of the intraparietal into the fissure of Sylvius is effected in precisely the same manner. A small variable opercular furrow extends upwards into it, and acts as a loose bond of union between it and the postcentral sulcus of the insula. I am not able to speak with the same certainty of the two præcentral sulci. These two furrows, the one on the surface of the insula and the other on the surface of the mantle, do not maintain the same prominence which they present in the fœtus, and consequently their relations in the adult cannot be studied

with the same precision. At the same time, I may say that everything is in favour of the view that, in those cases in which the præcentral furrow of the mantle opens into the Sylvian fissure, it does so by the development of an opercular furrow intermediate between it and the præcentral sulcus of the insula. When we come to deal with the development of the sulci on the insula, we shall see that the præcentral sulcus becomes slightly shifted in its position in a forward position, so that it does not accurately coincide in its direction in the adult with the corresponding furrow of the frontal lobe.

But, further, the inferior frontal convolution stands in close connection with the portion of the anterior insula which is placed in front of the præcentral sulcus of the island of Reil. Thus the gyrus brevis primus, in its upper part, lies under cover of the pars triangularis, and not infrequently pushes itself across the upper limiting sulcus of Reil to form a direct connection with this part of the lower frontal convolution. The gyrus accessorius stands in precisely the same relation to that part of the orbital portion of the inferior frontal convolution which lies between the anterior horizontal limb of the Sylvian fissure and the posterior extremity of the external orbital sulcus. The connection between the sulcus which limits the gyrus accessorius below, and the external orbital sulcus on the orbital face of the frontal lobe, is also apparent. The former sulcus is continued on to the deep surface of the orbital operculum, and in certain cases cuts right through it to form the external orbital limb of the Sylvian fissure. Benedikt terms this limb the "hinderpiece" of the external orbital sulcus, and remarks that he has observed the two fissures to become continuous with each other. This condition I have never seen; but, be this as it may, I regard the external orbital limb of the Sylvian fissure in the same light as I do the inferior transverse sulcus of Eberstaller. It is a secondary fissure in the operculum, which is to be regarded as an intermediate piece between the sulcus on the insula which bounds the gyrus accessorius below and the external orbital sulcus on the orbital face of the frontal lobe.

But a very considerable amount of variation is to be noted in the arrangement of the gyri in the fore part of the insula, and it is of importance to observe that this goes hand in hand with

variations in the corresponding part of the inferior frontal convolution. A disturbance in the condition of the one is generally accompanied by a disturbance in the condition of the other.

A study of the manner in which the convolutions and sulci of the insula are developed reveals many points of high importance and interest. Up to the middle of the fifth month the surface of the insula remains perfectly smooth, but long before this there is a marked indication of its division into a frontal and a parieto-limbic portion. From its very earliest appearance the fossa Sylvii is encroached upon below by the vallecula Sylvii. When the hemisphere is viewed in profile the latter region appears as a semilunar depression, which indents the lower part of the Sylvian fossa, and occupies a position between the extremity of the temporal lobe and the under aspect of the frontal lobe. This notch or depression is surrounded above by a rim which represents the external root of the olfactory lobe, and it divides the lower part of the Sylvian area into two nearly equal portions, viz., an anterior portion, which joins the under surface of the frontal lobe, and a posterior part, which runs into the extremity of the temporal lobe. As the temporal operculum begins to take shape, and the extremity of the temporal lobe grows forwards so as to overshadow the Sylvian vallecula, the hinder part of the lower portion of the insula becomes hidden from view, whilst the fore part develops into the pole of the insula. At the same time, the wide semilunar notch in the lower part of the insula, or, in other words, the outer extremity of the vallecula Sylvii, becomes gradually reduced in width, and converted into a narrow cleft or incision. Further, with the growth of the temporal operculum, the lower limiting furrow (lower part of the sulcus circularis Reilii of Schwalbe) becomes apparent.

When the front extremity of the temporal lobe of a fœtal brain (say at the fifth month) is examined, two very distinct gyri, which traverse it from above downwards immediately external to the uncus, are evident. The outer of these is the extremity of the temporal operculum; the inner gyrus is continuous with the hinder part of the insula, and lies close to the outer side of the front end of the uncus, which, as is well known, very early takes shape. These may be termed the primitive polar gyri of the temporal lobe. A faint furrow intervenes

between them, but they are rendered more conspicuous by their own prominence than by the presence of the intervening sulcus. This sulcus is quite continuous with the posterior limiting sulcus of the insula, and when followed round the temporal pole it is seen to be directly in the line of the depression, along the bottom of which the collateral fissure is afterwards developed. Later it becomes a distinct and sharply-cut fissure, the incisura temporalis of Schwalbe. Coincident with this change, the inner of the two polar gyri, which is continuous with the hinder part of the insula, decreases in size and prominence until, in the eighth month, it becomes more or less completely incorporated with the uncus.

The inferior limiting sulcus of the insula, the incisura temporalis, which bounds the extremity of the uncus on its outer side, and the collateral fissure lie, therefore, all in the same line, and may be regarded as the bounding fissures of the temporal lobe. The inferior limiting sulcus of the insula marks it off from the island of Reil, while the incisura temporalis and the collateral fissure intervene between it and the great limbic lobe. But further, the growth forward of the extremity of the temporal pole is merely a growth of the anterior part of the temporal operculum, which, as we have seen, first shows as the outermost of the two primitive polar gyri. It extends forwards to meet the orbital operculum, and finally comes to overlap it to a very considerable extent. There is no part of the opercular arrangement which ultimately attains so great a depth.

Using the term "temporal pole," therefore, in its more restricted sense (that is to say, excluding the extremity of the uncus), it is important to note that this part of the temporal lobe owes its existence entirely to the forward growth of the operculum.

But in the later stages of development the very evident relation which the inferior limiting sulcus of the insula bears to the incisura temporalis and the collateral fissure becomes obscured. Towards the end of fœtal life the deep surface of the temporal pole becomes scored with two or three transverse sulci. These have been figured and described in the adult brain with great care and exactness by Eberstaller.[1] The same

[1] *Anatomischer Anzeiger*, No. 24, November 1887, p. 745.

author has very correctly pointed out that in the adult the lower limiting sulcus of the insula ends in front by running forwards upon the deep surface of the temporal pole, and taking up a position parallel to and behind these transverse sulci. This, however, is a purely adventitious arrangement, which is brought about through one of the transverse sulci, about the ninth month of fœtal life, running into the limiting sulcus of Reil, and thus becoming continuous with it. In the adult brain, therefore, the true relations of the inferior limiting sulcus of the insula are somewhat misleading.

The examination of the fœtal brain renders the relationship which exists between the sulci and convolutions of the insula and the fissures and gyri on the surface of the mantle still more obvious. Three radial "Primärfurche" appear in each region, not only at the same stage in the development of the brain, but also, as a rule, in very much the same order. In the latter half of the fifth month the central sulcus becomes evident as a faint linear furrow, which runs upwards and backwards from the lower part of the Sylvian fossa. From the very first it lies accurately in the line of the fissure of Rolando, and it appears at the same date. At this period the sulcus centralis is situated much nearer to the hinder end of the insula than in the later stages, because the Sylvian fossa has not yet attained its full degree of backward extension. In all the subsequent changes which occur in this region the sulcus centralis remains absolutely fixed and stationary, and sways neither in a forward nor in a backward direction.

The præcentral sulcus is developed a little later than the central sulcus, but as a general rule before the end of the fifth month. It lies accurately in line with the sulcus præcentralis inferior on the surface of the frontal lobe; but in its subsequent history it is not so stationary as the sulcus centralis. In the last four weeks of fœtal life its upper end generally moves forwards to a slight extent, so that in a measure it loses its accurate relationship to the corresponding sulcus on the surface of the mantle. Another peculiarity of this sulcus consists in the fact that in the early stages of its development it generally outstrips the central sulcus, and for a time it becomes the best marked furrow on the surface of the insula. This pre-eminence it

loses in the eighth month. In fact, as we have seen, it is in the adult the feeblest sulcus of the series. In connection with this it is of interest to note that very much the same thing frequently occurs in the case of the præcentral fissure of the frontal lobe. In many cases, more especially when it appears earlier than the fissure of Rolando, the præcentral sulcus of the mantle is extremely deep and much the most evident of the three radial "Primärfurche." Later on, however, it falls behind the others in its degree of development. Pansch[1] held it as a law that there is a general correspondence between the depth of a furrow and its period of origin. In other words, the earlier a furrow makes its appearance in the fœtal brain the deeper will it be in the adult brain in comparison with others of more recent development. This law is no doubt true in the main, but there are many exceptions, and the case in point is one of these.

Guldberg, in his excellent paper on the "Morphology of the Island of Reil,"[2] has mistaken in the fœtal brain the sulcus præcentralis for the sulcus centralis of the insula; and to account for its subsequent change in position, he has supposed that its upper end is gradually pushed backwards, until it assumes a situation and direction which brings it into a line with the fissure of Rolando. To account for this change of position, he is obliged to assume "that the frontal lobe of the cerebrum increases during growth relatively more than the part which is placed behind the sulcus centralis insulæ." We know that this is not the case, because if it were we should also have the position of the fissure of Rolando affected; and this is almost as stationary and fixed after its first appearance as the sulcus centralis insulæ. But, further, the Sylvian fossa has a growth peculiar to itself. The anterior end of the fossa maintains throughout its entire growth very much the same relative position, whereas the posterior end extends rapidly backwards. But this backward growth does not affect the entire area. It seems to be brought about by a continual backward retreat of the surrounding mantle-wall, so that the position of the sulci when once they are laid down is not interfered with.

[1] "Einige Sätze über die Grosshirnfaltungen," *Centralblatt für die Medicinischen Wissenschaften*, No. 36, September 8, 1877.

[2] *Anatomischer Anzeiger*, October 1887, No. 21

The post-central sulcus is much later in making its appearance. As a rule, it does not show until the middle of the sixth month, or even later. Its development coincides with that of the intraparietal sulcus. It would not be possible for this sulcus to take form at a date much earlier than this, because the ground which it occupies in the insula has hardly been included within the Sylvian area at the time when the two other sulci appear.

The period at which the three radial furrows of the insula can be best studied in their relations to the corresponding sulci on the surface of the cerebral mantle is in the latter part of the seventh month, or the first part of the eighth month. Still it is right to state that exceptional cases are met with, and I have observed fœtal brains of this stage in which the insula was perfectly smooth. Further, there is good reason to believe that in the development of the sulci and gyri the right insula is usually in advance of the left, and also that the process is greatly retarded in the female brain. Rudinger[1] has contended that all the convolutions of the cerebrum of the female fœtus are backward in their growth as compared with those of the male fœtus. Upon this point I have not been able to satisfy myself, because we meet with cerebral hemispheres belonging to the same period of development, and the same sex, which present very different degrees of complexity. In the case of the insula, however, the law certainly does appear to hold good.

The following is a brief account of the condition of the insula in those fœtal brains which I have specially examined with the view of determining the development of the gyri and sulci:—

I. 5 *to* 5½ *months*—6 hemispheres examined.

In three—Insula perfectly smooth (viz., 1 right and 2 left).

In two—Insula with sulcus centralis only—(1 right and 1 left).

In one—Insula with sulcus præcentralis and sulcus centralis (right).

II. 5½ *to* 6 *months*—10 hemispheres examined.

In two—Insula perfectly smooth (both left).

[1] Ueber die Unterschiede der Grosshirnwindungen nach dem Geschlecht beim Fœtus und Neugeborenen München, 1877.

In four—Insula with sulcus centralis only (2 right and 2 left).

In four—Insula with sulcus centralis and sulcus præcentralis (3 right and 1 left).

III. 6 *to* 6½ *months*—8 hemispheres examined.

In one—Insula perfectly smooth (right).

In one—Insula with sulcus centralis alone (left).

In three—Insula with sulcus centralis and sulcus præcentralis (2 right and 1 left).

In three—Insula with the three sulci (2 right and 1 left).

IV. 6½ *to* 7 *months*—3 hemispheres examined.

In each of these the insula showed all the three sulci.

In the latter weeks of intra-uterine life the development of the gyri and sulci on the surface of the insula takes place very rapidly, consequently, at birth, the insula presents very nearly the same convolution pattern that it does in later life. All the details are filled in. Further, the præcentral furrow, instead of having fallen back, as Guldberg supposed, to form the sulcus centralis, has in reality moved very slightly forwards, so that it does not lie so accurately in line with the corresponding furrow on the mantle as it did on its first appearance. This is brought about by the formation of that triangular depression which marks off the gyrus brevis secundus from the gyrus centralis anterior (gyrus brevis tertius).

A NOTE ON THE RADIO-CARPAL ARTICULATION.

By FRANCIS J. SHEPHERD, M.D., *Professor of Anatomy, M'Gill University, Montreal.*

(Read at the meeting of the Association of American Anatomists held in Boston, U.S.A., December 1890.)

ONE of the most complete and generalised forms of carpus is seen in the Water-tortoise. In this animal it consists of two rows of bones, the distal row containing five bones, and the proximal three, with a central bone between the two rows. The bones of the first or proximal row are the "radiale," "ulnare," and "intermedium," which correspond in the human carpus to the scaphoid, semilunar and pyramidal bones; the radiale and ulnare articulate with the radius and ulna, while the intermedium, as its name implies, is placed between the two others, and articulates with both the radius and ulna. Now the same thing occurs in the human carpus. The scaphoid articulates with the radius, the pyramidal bone with the ulna or with the cartilage interposed between its upper surface and the ulna, while the semilunar bone (intermedium), by its upper surface, articulates with radius, and also with the meniscus, which separates it from the ulna. The object of my paper is to show that the semilunar always articulates with the ulna, not immediately but by means of the interposed cartilage or meniscus. In only a few text-books[1] of anatomy is this fact stated. The majority state that the upper surfaces of the scaphoid and lunar bones correspond with the radius, and that the upper surface of the pyramidal bone corresponds with the triangular fibro-cartilage, which separates the ulna from the wrist-joint. Henle many years ago taught the proper method of articulation, and described it in his *Handbuch;* but most of the text-books on anatomy have ignored his observations.

[1] *E.q.*, Henle, Quain, Cunningham, Ellis. In describing the semilunar bone, all the works on Anatomy I have consulted fail to mention the connection of the bone with the meniscus.

If one looks at the upper surface of the semilunar, one will find that it is somewhat triangular in shape, the rounded angle of the apex of the triangle being toward the pyramidal bone, and continuous with its upper surface and the base towards the scaphoid. In the fresh state, when this surface of the semilunar bone is covered with cartilage, a distinct line may be seen separating the surface, articulating with the radius from that opposite the fibro-cartilage. This latter surface, from the examination of a number of subjects, I find varies considerably in size and extends more to the palmar than the dorsal surface. When the upper articular surface of the pyramidal bone is of large size, then the facet on the lunar bone opposing the meniscus is small, and *vice versa*. In some cases the upper surface of the pyramidal bone may not be in contact with the fibro-cartilage at all, except in extreme adduction; when this occurs there is a large surface of the semilunar bone in contact with the fibro-cartilage, the small articular facet on the pyramidal being in contact with the capsule of the joint. In other cases the portion of semilunar bone opposite the meniscus is so small as hardly to be noticeable, consisting merely of a very narrow strip, a line or two wide, on the ulnar side of the upper articular surface. Years ago, not knowing what had been done by Henle, my attention was directed to this articulation of the lunar and pyramidal bones whilst investigating the frequency of perforation of the triangular fibro-cartilage. I frequently noticed that when there was a perforation of the meniscus it was due to some form of synovitis or arthritis, and that the surface of the carpus opposite the perforation was *always* a portion of the semilunar bone. When the opening was small this surface was dull, and did not glisten like the rest of the cartilage; later, as the opening *wore* larger and friction became greater, portions of the cartilage became roughened and loose; later still, the cartilage disappeared altogether leaving a spot of bare bone, which corresponded to the opening in the fibro-cartilage. If the process still went on, this bare bone became polished or eburnated as well as the lower end of the ulna, which went through the same changes, though not so rapidly. In such cases I was always struck by the fact that this roughened or eburnated surface was of larger extent on the semilunar than

on the pyramidal bone. It is not uncommon to see the articular surface of the lower radio-ulnar articulation and the surface of the carpus opposite the disappearing meniscus disorganised, whilst the rest of the wrist-joint remains perfectly healthy. Perforation of the meniscus is, in my experience, rarely normal; in nearly every instance I have found it due to some pathological condition, caused either by injury to or disease of the lower radio-carpal articulation.

[A number of preparations, both moist and dry, illustrating this paper, were exhibited to the members of the Association.]

CONTRIBUTIONS TO THE PHYSIOLOGY AND PATHOLOGY OF THE BLOOD. By ROBERT MUIR, M.A., M.D. (EDIN.), *Assistant to the Professor of Pathology, Edinburgh University.* PART II. (PLATE IX.)

(*Continued from* page 277.)

THE LEUCOCYTES.

WITHIN recent years the leucocytes have been the subject of much controversy, and they have in turn been said to have an important function in many different physiological and pathological processes. Whilst formerly they were generally grouped together as a single class with somewhat ill-defined characters, they have now been divided into different classes on various principles of classification, and there is perhaps a tendency to separate the varieties too distinctly from one another. Histological differences apparently slight may, however, come to be of importance in the solution of certain problems, and it will be shown that in various pathological conditions the different varieties of leucocytes undergo changes of a very definite character. I shall first describe the characters of the leucocytes seen in normal human blood.

It has long been known that in human blood in the fresh undiluted condition, a few white corpuscles can be seen possessing coarse highly refracting granules, whilst most of them are finely granular or almost homogeneous. In the latter larger class, two divisions at least may be made with considerable distinctness. The one includes all the smallest leucocytes, which measure 6 μ to 7·5 μ in diameter [most being a little over 7 μ], and are nearly homogeneous, possessing only a few granules of extreme fineness. Sometimes a large nucleus, filling the corpuscle almost completely, is visible, sometimes it is not. It can, however, always be revealed by the addition of weak acetic acid, which brings into view a narrow rim of homogeneous protoplasm surrounding it, the protoplasm being slightly swollen up at the same time. These corpuscles have a refractive index

Fig.

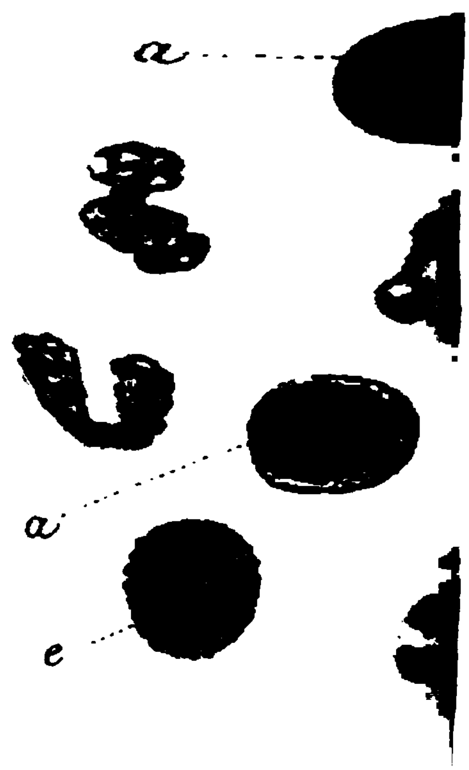


Fig.

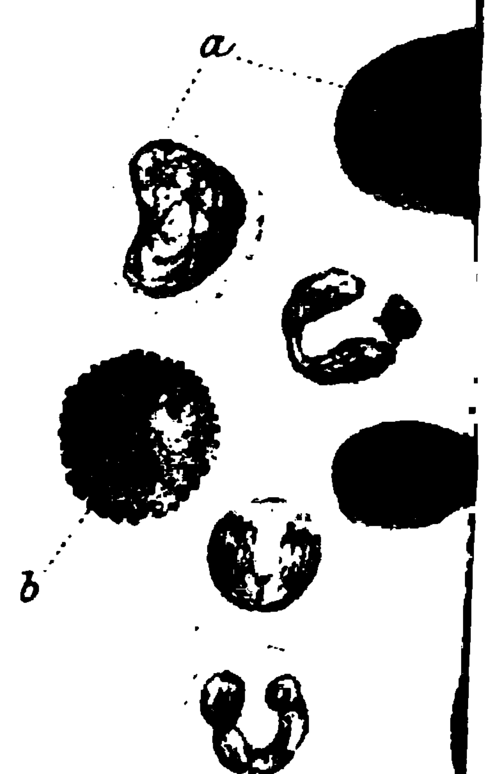
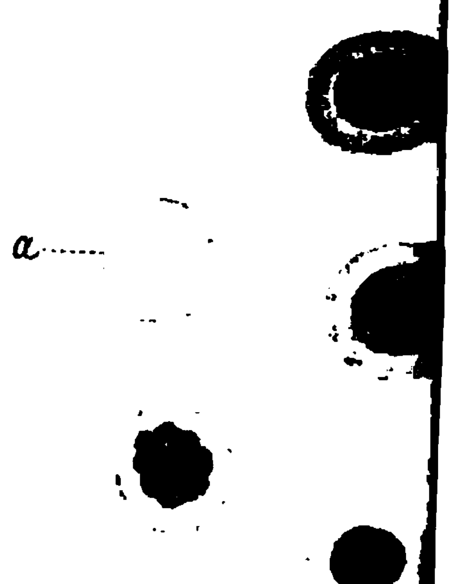


Fig.



R. Muir, del.

very near that of the serum, and consequently may sometimes be overlooked on a hasty examination. The second division includes corpuscles of a larger size, which measure 7·5–10 μ in diameter and are finely granular. In the fresh condition no nucleus is visible. They are much more easily seen than the smaller variety, as they differ more in refraction from the surrounding serum. Most of them are perfectly spherical, but some may show some irregularity of outline, the most common being a tailing out and thinning off at one side. This is probably due to arrested amœboid movement. In preserving fluids they are always spherical. On a warm stage most of the leucocytes of this class exhibit very active amœboid movements, changing their form and creeping about in the well-known manner. Acetic acid brings the nuclear substance into view as a highly refracting mass, sometimes forming one large nucleus which almost completely fills the cell, sometimes broken up into several nuclei of smaller size, which are variously arranged but whose exact structure cannot be studied in this way.

The coarsely granular leucocytes are generally 8–10 μ in diameter. The granules rarely cover the cell completely, and one or two oval nuclei can sometimes be seen. According to Max Schultze these corpuscles have protoplasm of firmer consistence than the finely granular, and the processes which they protrude on a warm stage have a more definite outline. They also are typically amœboid; in fact Lavdowsky[1] considers their movements to be the most rapid of all the leucocytes.

Corresponding divisions of leucocytes have been made by various observers. Schultze,[2] *e.g.*, describes finely granular and coarsely granular corpuscles, and divides the former into three classes. The first includes the smallest corpuscles, which are uninucleated, and possess no amœboid movement. The second includes corpuscles which are about the size of a red corpuscle, are uninucleated, with a little protoplasm surrounding the nucleus, and on the warm stage exhibit changes of form but have no creeping movement. The large typically amœboid

[1] Lavdowsky, "Mikroskopische Untersuchungen einiger Lebensvorgänge des Blutes," *Virchow's Archiv*, Bd. xcvi. p. 80.

[2] Schultze, "Ein heizbarer Objecttisch.," *Archiv f. mikr. Anat.*, Bd. i. p. 1.

corpuscles, 9–12 μ in diameter, with many nuclei, constitute the third class. Hayem[1] divides the leucocytes into three classes,—the coarsely granular, the finely granular, and the hyaline,—the last class being formed by the smallest corpuscles. I believe that Hayem is correct in fixing the diameter of the largest leucocytes in normal blood at 10 μ. It is quite exceptional to meet with forms of larger size in the fresh blood, though they appear of larger size in film preparations, because they may be somewhat flattened out, and in some preserving fluids in which they become swollen up. Accordingly, measurements made by either of these two methods are quite fallacious.

In dried films stained in various ways corresponding varieties of leucocytes are seen. The smallest corpuscles possess a single round nucleus which stains pretty deeply and has a slightly granular appearance, which, by means of the highest powers, can be seen in many corpuscles to be due to a very fine reticulum within the nucleus (fig. 1, *a*). The surrounding protoplasm is always small in amount, being invisible in some corpuscles, and is generally stained darkly—in some cases almost as darkly as the nucleus. Larger corpuscles of similar structure are also seen, in which, however, the surrounding protoplasm is generally more abundant. These may be called the smaller and larger uninucleated leucocytes respectively. Some of the latter may be formed in the blood from the former by a simple increase in size, others enter the blood as large uninucleated corpuscles, as they may be found in the thoracic duct.

Most of the corpuscles, however, are composed of a relatively large amount of protoplasm, in which the nuclear substance lies variously arranged. The protoplasm of these corpuscles is almost unstained, whilst the nuclei are very deeply stained. The commonest form is that possessing several round or oval nuclei, some of which are often connected by bands or threads of nuclear substance, the arrangement exhibiting the greatest diversity (fig. 1, *c*). Pouchet[2] has described the typical leucocyte as possessing four distinct nuclei, but there is really no definite number, and they are rarely quite separate from one another. I have seen as many as nine nuclei in a corpuscle of ordinary

[1] Hayem, *Du Sang*, p. 103.
[2] Pouchet, *Quart. Jour. of Mic. Sci.*, 1880, p. 221.

size, though this was in a pathological condition. The size of the nuclei varies, but is generally 2·5–3 μ. Each nucleus has a definite structure, which is best seen in thin parts of the film. The darkly stained chromatin-substance sometimes forms a sort of membrane bounding the nucleus, within which there is seen lying a small portion of chromatin constituting a nucleolus, or pseudo-nucleolus; sometimes it is arranged as a distinct network. The substance filling the insterstices between the chromatin within the nucleus is almost unstained with methyl-blue, and in double staining with methyl-blue and fuchsin is of a pale pinkish colour. The bands connecting the nuclei are evidently composed of chromatin, being rarely more lightly stained than the nuclei. Some have called only the corpuscles whose nuclei are quite distinct from one another "multinucleated," and have applied to those in which the nuclei are more or less joined together the term "leucocytes with polymorphous nuclei." As the first are merely a further stage of the second, and have practically the same structure, I have included them under the one term.

Many, if not all, of the multinucleated forms are derived from the larger uninucleated forms, and the following would appear to be the method of transformation. One often sees a uninucleated corpuscle, whose nucleus is indented at one point, showing thus a greater amount of protoplasm, which is, however, more darkly stained than the protoplasm of the fully developed multinucleated form (fig. 1, *b*). The nuclear mass then becomes somewhat more condensed and shows signs of lobulation, whilst more protoplasm is visible around it. A further stage is seen in which the nucleus becomes more broken up, often presenting the form of a ring or of a horse-shoe-shaped structure with thickenings at parts—the future nuclei. These thickenings gradually separate from one another, till they remain connected merely by threads of nuclear substance, and some may lie quite free. The nuclei have at this stage assumed their typical appearance. During the process, the staining of the protoplasm becomes gradually lighter, till in the typical multinucleated corpuscle it is scarcely coloured at all by nuclear stains such as methyl-blue. The mode of transformation is well seen by double-staining with methyl-blue and fuchsin. In the earlier

forms the protoplasm is coloured somewhat darkly of a blue colour, with a slight reddish tint, whilst in the later forms the blue colour disappears from the protoplasm, which is tinted by the fuchsin only, and very slightly. There therefore takes place a condensation or concentration of the chromatin with clearing of the protoplasm. Forms intermediate between the uninucleated and multinucleated leucocytes are often the largest corpuscles present, and their number varies in different conditions. They are well seen in the blood of the dog.

The granules of coarsely granular corpuscles were first shown by Ehrlich[1] to stain deeply with eosine and acid aniline stains such as aurantia, indulin, acid-fuchsin, &c. He therefore applied to them the term "eosinophile" (*v.* fig. 1, *d*). They are best seen in films fixed by heating and stained with a solution of eosine in glycerine or water. Ehrlich[2] considers that these corpuscles are chiefly formed in the bone-marrow. There also occur coarsely granular corpuscles in human blood, whose granules are deeply stained by methyl-blue and other basic aniline stains. The granules cover a varying proportion of the surface, and the protoplasm is stained of a lighter blue, while the nucleus or nuclei are indistinctly seen. Those corpuscles occur in very small numbers in perfectly normal blood, but they are numerous in certain pathological conditions (figs. 1*e*, 3*b*). Ehrlich[3] has also shown that in the protoplasm of the ordinary multinucleated leucocytes, there are fine granules which have a "neutrophile" reaction, being coloured of a violet tint by a watery solution of methyl-blue and acid-fuchsin together.

In dried films we therefore find varieties of leucocytes corresponding to those found in the fresh blood, but the class of large finely granular leucocytes, though chiefly composed of multinucleated corpuscles, is seen to include also a few large uninucleated and intermediate forms.

I may add, that in sections of blood made as described on page 258, the same varieties of leucocytes are seen, but the nuclei of the uninucleated corpuscles are more sharply defined

[1] Ehrlich, "Ueber die specifischen Granulationen des Blutes," *Arch. f. Anat. u. Phys.*, 1879, Physiol. Abtheil., pp. 166, 571.

[2] Ehrlich, *Deutsch. Med. Woch.*, 1883, p. 670.

[3] Ehrlich, "Beiträge zur Physiologie und Pathologie der verschiedenen Formen der Leucocyten," *Zeit. f. Klin. Med.*, Bd. i., 1880, p. 553.

from the surrounding protoplasm, and contain larger granules of chromatin than in film preparations. The arrangement of the nuclei and the characters of the protoplasm as regards staining are, however, practically the same.

It is difficult to determine whether or no the leucocytes multiply by division in the blood and, if so, to what extent. I can find no evidence that the multinucleated leucocytes break up into several small corpuscles, each nucleus forming a new corpuscle, as Norris[1] believed. The smallest uninucleated corpuscles of the blood differ too much both in size and structure from the nuclei of the multinucleated leucocytes to allow of such a mode of development. That some of the larger multinucleated leucocytes may divide into two multinucleated corpuscles of similar structure is quite possible, but I have not been able to convince myself that this actually takes place. Amongst the corpuscles which I have described as intermediate forms, one often sees appearances suggestive of the occurrence of division. Such corpuscles are often of oval shape, and the nuclear substance is arranged in two masses, one towards each end. Much more rarely one sees two distinct round nuclei of equal size within a leucocyte. I have, however, seen a leucocyte in the blood of a dog fixed in osmic acid, in which the process of division was almost completed, each half containing a large single nucleus almost completely filling it, and the two halves being connected by a narrow neck of protoplasm. I accordingly believe that actual division does take place in the blood, chiefly on the part of the uninucleated corpuscles and forms but little removed from them, but the process is not a common one. The fact that many of such corpuscles are larger than the multinucleated leucocytes would also be in favour of its occurrence. It would appear to take place by a simple division of the nucleus into two, followed by a constriction and cutting through of the protoplasm. Hitherto I have failed to find mitotic figures amongst the leucocytes of the blood either in health or in leucocythæmia, in which disease Müller[2] says he has seen them.

The peculiar arrangement of the nuclei of the multinucleated

[1] Norris, *The Physiology and Pathology of the Blood.*

[2] Müller, "Zur Frage der Blutbildung," p. 68, from *Sitzb. d. k. Akad. d. Wis. zu Wien*, Bd. xcviii. Abtheil. iii.

leucocytes has been variously interpreted. Löwit[1] considers that it is the result of a fragmentation of the nucleus which is to be regarded as an evidence of degeneration, and which is followed by the dissolution of the corpuscle. I think that this view is incorrect, for the following reasons:—The process of transformation of the uninucleated into the multinucleated leucocyte is rather one of differentiation and elaboration to a more complex structure than one of fragmentation, and the nuclei of the latter often show a distinct network and are exceedingly deeply stained by nuclear stains. We have also the fact that the multinucleated leucocytes are most actively amœboid, and it is evident that the arrangement of the nuclei is peculiarly adapted for the remarkable changes which occur in the form of those corpuscles. Quite a different view of the appearances in these corpuscles is taken by Arnold.[2] He considers them to represent stages in a process of nuclear diversion which he has studied chiefly in the giant-cells of the bone-marrow, and which he has called "indirect fragmentation." He distinguishes four stages in the process. (1) The chromatin becomes more abundant, the chromatin threads more numerous; (2) an inpushing of the nuclear wall takes place at various points, so that very complicated figures often arise; (3) a drawing together of the chromatin at various points is seen, which results in the formation of darkly stained structures joined by more lightly stained threads; (4) there occurs a cutting off of the protoplasm either at the periphery or throughout the cell. Most of the corpuscles of the blood would be in the third stage. It is a multipartite nuclear division by indirect fragmentation. I have not been able to put this interpretation on the appearances seen, and I fail to find evidence that the multinucleated condition of the leucocyte is to be associated with the division of the cell. Arnold holds that the leucocytes also multiply by direct division.[3] Müller also opposes the theory that the nuclei of the multinucleated leucocytes are the result of a

[1] Löwit, "Ueber die Bildung rother und weisser Blutkörperchen," 1883, p. 18, from *Sitzb. d. k. Akad. d. Wis. z. Wien.*, Bd. lxxxviii. Abtheil. iii.

[2] Arnold, "Weitere Beobachtungen über die Theilungsvorgänge an de Knochenmarkzellen und weissen Blutkörperchen," *Virchow's Archiv*, Bd. xcvii. p. 107.

[3] Müller, *Op. cit.*, p. 22.

degenerative process, yet neither can he find evidence that the multinucleated condition leads to a corresponding division of the cell.

There can be no doubt, from an examination of the cells in the various blood glands and their efferent channels, that most of the leucocytes are produced there, and enter the blood in their uninucleated condition. In the lymphatic glands of the dog, for example, examined immediately after death, most of the corpuscles are seen to be of the small uninucleated variety, a few are larger—8–11 μ—whilst typically multinucleated leucocytes are exceedingly scanty. In the thoracic duct too, practically all the leucocytes are uninucleated corpuscles of various sizes, most being 6·5–9·5 μ. Few even of the largest size show signs of change into the multinucleated condition, and typical multinucleated corpuscles I believe are not found if one is careful to exclude the admixture of blood. The cells in the splenic reticulum are also uninucleated, though numerous multinucleated leucocytes are present in the blood flowing through the spleen. Accordingly, if we examine a scraping of the spleen-pulp after death scarcely any multinucleated leucocytes are found, but they are abundant in the blood drawn from the spleen during life by means of a puncture or a small incision. I have found that the blood of the splenic vein contains a larger proportion of uninucleated corpuscles than the blood of the artery, though the absolute number of the leucocytes is very slightly increased (*v. infra*). Löwit[1] gives a similar statement with regard to the bone-marrow. He found in the veins carrying the blood from the bone-marrow a much larger proportion of uninucleated leucocytes than in the arteries, the number of the uninucleated being nearly equal to that of the multinucleated—a condition very similar to what I found in the splenic vein. Löwit also states that uninucleated corpuscles are slightly more numerous in the systemic veins and the right side of the heart than in the arterial system.

From the fact that the total number of leucocytes in the blood after passing through the spleen is little altered, whilst the proportion of uninucleated forms is increased, it follows that a number of multinucleated corpuscles disappear from the blood

[1] Löwit, *Sitzb. d. k. Akad. d. Wis. zu Wien*, Bd. xcvi. Abtheil. iii. p. 129.

during its passage. These must either be transformed into uninucleated corpuscles or be broken down. If they divided into uninucleated corpuscles corresponding to their nuclei, the total number of leucocytes in the vein would be considerably increased, which is not the case, and I think it very improbable, for various reasons, that the nuclei of a multinucleated corpuscle would again fuse together to form a single nucleus. I accordingly believe that in the spleen some of the multinucleated leucocytes are broken down, while new uninucleated corpuscles are added to the blood. The presence of a large quantity of granular matter between the splenic corpuscles, seen both when the juice of the spleen is examined in its fresh condition and also in dried films, would favour such a view. Ehrlich [1] also considers that multinucleated leucocytes are broken down in the spleen, basing his belief on the fact that the granules mentioned have the same staining reaction ("neutrophile") as the granules in the protoplasm of the multinucleated leucocytes, whilst none of the ordinary splenic corpuscles contain such granules.

As is well known the multinucleated leucocytes pass out of the vessels by diapedesis in inflammation, especially if it is followed by suppuration, and are found in great numbers in the lymphatic spaces of the tissues or in the muco-purulent secretion of mucous membranes. Pus corpuscles have practically the same structure as those leucocytes, though their nuclei often show signs of degeneration. (The latest theory of Ziegler[2] is that, in the repair of wounds, &c., the multinucleated leucocytes are for the most part taken up and destroyed by the growing cells of the tissue, forming, in fact, the food of those cells, and take no active part in the formation of the new tissue. The emigrated uninucleated leucocytes pass into the multinucleated form, and are then destroyed by the tissue cells.) In normal conditions, on the other hand, the corpuscles in the connective-tissue spaces are practically all of the uninucleated variety, and similar corpuscles are found in the afferent lymphatics. I have examined the contents of the afferent lymphatics of the leg of a rabbit during life and of a dog immediately after death, and have found all the corpuscles to

[1] Ehrlich, *Charité Annalen*, 1884, p. 107.
[2] From Abstract in *Brit. Med. Jour.*, 1890, ii. p. 360.

be uninucleated and mostly of small size, with a scarcely visible zone of protoplasm round the nucleus. Accordingly, multinucleated leucocytes are found in large numbers in the normal state in the blood only, and are formed from uninucleated corpuscles, which are constantly being added from the blood glands. The transformation is probably a rapid one, seeing that the number of transitional forms is comparatively small, and, in view also of the rapidity with which the number of the leucocytes may be increased or diminished in certain conditions, it is probable that their life in the blood is a short one. They must be destroyed in great numbers somewhere, and I have given reasons for believing that the spleen is one of the seats of destruction.

With regard to the number of leucocytes in normal human blood, there can be no doubt that the original proportions to the red corpuscles, given by Welcker and Moleschott as 1 : 335 and 1 : 357 respectively, are much too high. Hayem, Thoma, and Halla place the normal proportion at from 1 : 1000 to 1 : 500. Afanassiew considers 1 : 600 the average normal proportion, and Halla says that if the proportion exceeds 1 : 400 the condition is abnormal. My results would lead me to say that a number of 10,000 per cmm., *i.e.*, a proportion of 1 : 500 is rarely exceeded without some pathological condition being present. The minimum, on the other hand, rarely falls below 6000.

In pathological conditions, in which the number of leucocytes is altered, we have to determine not only their number, but also what varieties of leucocytes are increased or diminished. It will also be shown that cells may appear which are not normally present in the blood. From the examination of normal blood on many occasions I have found that the proportion of uninucleated to multinucleated leucocytes is approximately 1 : 2 (including for convenience under the term "uninucleated" both the small and large uninucleated corpuscles and most of the transitional forms), or, in other words, the typical multinucleated corpuscles number about 66 per cent. of all the leucocytes. In the blood of the dog the proportion is practically the same. Ehrlich places the number of multinucleated corpuscles at 65–70 per cent., and Einhorn[1] finds

[1] Einhorn, "Ueber das Verhalten der Lymphocyten zu den weissen Blutkörperchen," Inaug. Dis., Berlin, 1884, *Ref. Fortschr. d. Med.*

that the "lymphocytes," which, however, include only the *small* uninucleated corpuscles, number 20–25 per cent. Hayem[1] finds the proportion of hyaline, finely granular, and coarsely granular leucocytes of the blood to be 23, 70, and 7 per cent. respectively, but as a few uninucleated leucocytes belong to both the second and third of these classes this statement closely agrees with what I have given. Ehrlich finds eosinophile corpuscles to be 2–4 per cent. In the course of my observations I found that the proportion of the two varieties (uninucleated and multinucleated) remained tolerably constant in a great number of individuals in different conditions, but that in certain diseases marked variations occurred, so that, on the one hand, the uninucleated corpuscles might exceed the multinucleated in number, or, on the other hand, the latter might be many times as numerous as the former. Accordingly, in most of my cases I have estimated the proportion of the two forms. This is easily done by staining dried films of blood with methyl-blue and counting the number of the two varieties in several fields of the microscope till about 200–300 in all have been counted. The proportion is then easily obtained.

The Red Corpuscles.

It is simply my intention to mention here the chief alterations which the red corpuscles undergo in disease, and to explain certain terms applied to the altered forms. Regarding their normal characters I have nothing new to say.

The red corpuscles may become altered in size, form, physical or chemical characters. Abnormal elements allied to them may also appear in the blood. Alterations in size are very common in association with diminution in the number of the red corpuscles, and different names have been applied. The term "megalocyte" ("Riesenblutkörperchen" of Gram[2]) is generally applied to corpuscles over 8 μ in diameter and of a nearly normal shape. Hayem[3] divides oversized corpuscles into "globules grands," which have a diameter up to 9·5 μ, and "globules géants," whose diameter exceeds that size. In the oversized corpuscles the concavity is generally less marked than in normal corpuscles, and their thickness is not usually increased

[1] Hayem, *Op. cit.*, p. 157.

[2] Gram, "Ueber die Grosse der rothen Blutkörperchen," *Fortschr. d. Med.*, 1884.

[3] Hayem, *Du Sang*, p. 334.

in proportion to their size. The term "microcyte" appears to have been applied to any small body in the blood resembling to any extent a red corpuscle, either in character or in shape, and hence much confusion has arisen from its use. Of such bodies I can distinguish at least the following varieties. (1) Small red corpuscles ("Zwergblutkörperchen" of Gram), which often have convex surfaces. These Hayem divides into "globules petits" and "globules nains," according as their diameter is above or below 6 μ. According to these authors they have concave surfaces when within the blood-vessels, and only alter their shape when the blood is shed. (2) Eichorst's[1] corpuscles. These, as described and figured by him, are small, deeply-coloured bodies of spherical shape and about 3 μ in diameter. They have a smooth surface and are always seen isolated in the spaces between the rouleaux. They were found by Eichorst in cases of pernicious anæmia, and were supposed by him to be characteristic of that disease. W. Hunter[2] found them in most of his cases, whilst others have found small corpuscles, but not deeply stained. They indicate destructive rather than regenerative changes in the red corpuscles. (3) Small rounded bodies which are formed by the detachment of buds from poikilocytes, often seen in severe anæmia. (4) Small deeply stained bodies of somewhat irregular shape—fragments of broken-down red corpuscles. They are found in poisoning with toluylendiamin, pyrogallic acid, &c. Similar bodies are sometimes found in the blood in typhoid fever (Afanassiew[3]). (5) Artificial products, fragments of crenated corpuscles, "coloured microcytes" of Lockhart Gibson.[4] (6) "Colourless microcytes," or blood-plates. Both the megalocytes and the microcytes of class (1) are present as normal elements in the blood of the fœtus.

The term "poikilocyte" was first applied by Quincke to red corpuscles of irregular shape, which he supposed to be characteristic of the blood in pernicious anæmia. They are, however, found in many other conditions. They often assume most extraordinary forms (v. figs. 5, 6, 7). Their production is generally ascribed to alterations in the blood serum, but their exact mode of formation is unknown. Hayem thinks that they are due to a too long survival of the characters of the hæmatoblasts, so that the substance of the corpuscles yields to external impressions, and that this condition is often associated with a deficiency of hæmoglobin. Poikilocytes, however, have all the physical properties of ordinary red corpuscles. Afanassiew considers them "real living elements" associated with blood regeneration as contrasted with degenerative products.

Regarding the presence of nucleated red corpuscles in the blood of the adult in pathological conditions there has been considerable difference of opinion, but they have now been seen by so many

[1] Eichorst, *C. f. d. med. Wiss.*, 1876; *Die progressive perniciose Anämie*, 1878.

[2] W. Hunter, "The Pathology of Pernicious Anæmia," *The Lancet*, 1888, ii. p. 555.

[3] Afanassiew, *Deutsch. Arch. f. Klin. Med.*, Bd. xxxv. p. 217.

[4] *Journ. Anat. and Phys.*, vol. xx. p. 107.

observers that their occurrence is beyond dispute. Amongst the first to observe them were Erb,[1] Boettcher,[2] and Klebs[3] who found them in leucocythæmic blood. Ehrlich[4] has found them in all varieties of anæmia, and divides them into "normoblasts" and "megaloblasts" according to their size, the former being characteristic of secondary (simple) anæmia, the latter of primary (pernicious) anæmia. A much rarer form, he finds, is the irregular nucleated red corpuscle—the "poikiloblast." Hayem,[5] on the other hand, during an eight years' experience in the examination of the blood, found them in only seven cases, three of which were cases of leucocythæmia, and Quincke[6] in a long series of cases of pernicious anæmia failed to find them in the blood either during life or after death. Afanassiew in his tables gives cases of leucocythæmia, typhoid, erysipelas, in which they were present, but I know of no other mention of their occurrence in conditions such as the two last. They have also been noticed by Einhorn[7] in anæmia, and in some other conditions. They can be recognised by any of the violet-tinted fluids mentioned above, or in films dried and stained, the latter method being specially convenient, as their perinuclear portion always stains differently from the protoplasm of the leucocytes.

Other alterations in the red corpuscles may simply be mentioned. Osler[8] has seen in the blood in leucocythæmia large cells containing red corpuscles. Hayem[9] describes leucocytes, coloured with hæmoglobin, which he has seen in some cases of profound anæmia, and also mentions alterations in the adhesiveness and viscosity of the red corpuscles in "phlegmasiæ," &c. Ehrlich[10] describes a degeneration in the red corpuscles by which the affected parts stain a crimson colour by acetic-eosin-hæmatoxylin, the normal corpuscles being of a bright orange colour, and notes some other changes.

I have not referred to the well-known alterations of the red corpuscles in malarial fevers, as I have not had an opportunity of studying them.

Pathological Alterations of the Blood.

I have examined the blood in upwards of a hundred cases of a great variety of pathological conditions, and in most of these

[1] Erb, *Virchow's Archiv*, Bd. xxxiv. p. 138.

[2] Boettcher, *Virchow's Archiv*, Bd. xxxvi. p. 342.

[3] Klebs, *Virchow's Archiv*, Bd. xxxviii. p. 190.

[4] Ehrlich, *Berl. Klin. Woch.*, 1880, p. 405; 1881, p. 43.

[5] Hayem, "Des globules rouges à noyau dans le sang de l'adulte," *Archives de Phys.*, 1883, p. 363.

[6] Quincke, *Deutsches Archiv, f. Klin. Med.*, Bd. xxv. p. 567.

[7] Einhorn, *op. cit.*

[8] Osler, "Cartwright Lectures" in *The Medical News*, 1886.

[9] Hayem, *Comptes rendus*, 1880, p. 225.

[10] Ehrlich, *Op. cit.*

the examination was made on several occasions. The points to which I have specially attended are—the numbers and sizes of the various elements, the varieties of leucocytes, the occurrence of nucleated red corpuscles, and the characters of the red corpuscles as regards shape, appearance, &c. The results are most conveniently given by means of a series of tables, each being followed by a verbal summary. Many of the cases in which the changes were slight I have not placed in the tables, but have simply given an abstract of the results.

I have placed the cases of anæmia first, and have arranged them in four chief classes according to their nature. Hayem has classified cases of anæmia according to their degree also, but this I find inconvenient, as the characteristic changes depend rather more on the nature of the anæmia than upon its intensity.

Explanation.—In the tables the column "Prop. A." signifies the proportion of uninucleated to multinucleated leucocytes. The term "numerous" applied to nucleated red corpuscles signifies that on an average one was found in every two or three fields of the microscope, "very few" that one or two could only be found after a diligent search; other terms signify intermediate conditions. A similar series of terms has been applied to the poikilocytes, but these occur in much greater abundance.

Traumatic or Post-hæmorrhagic Anæmia.

Summary.—If the anæmia be rapidly produced, even though very profound, the red corpuscles may be little altered in character. Slightly undersized corpuscles (6–7 μ) are rather more numerous than usual, and some may be paler and of less firm consistence; otherwise there may be no change. Thus in Case 1, even though the number of the red corpuscles was under a million per c.mm., almost all were of perfectly normal size and shape, poikilocytes being almost absent. If, however, the anæmia be severe and of long continuance, owing to repeated hæmorrhages, marked changes occur. The size of the corpuscles varies widely, small forms being sometimes found of a diameter as low as 3 μ, whilst megalocytes (up to 10·5 μ) are also found, though in comparatively small numbers. Poikilocytes appear, and may be present in large numbers, often showing the utmost

Table I.—*Traumatic Anæmia.*

Male. Anæmia due to Epistaxis.	,, 28.*	967,500	21,000	370,000	1:4·2	Very few.	Fairly
	,, 29.	977,500	21,000	332,000			
	Oct.	1,301,000	13,000	368,000			
	,, 3.	1,420,000	11,000	416,000			
	,, 10.	1,932,000	12,000	364,000			
Case 2— A. R., 25, F. Anæmia due to Post-partum Hæmorrhage.	Jan. 2.	1,[illegible]00	26,000	414,000			
	,, 3.	1,[illegible]00	23,000	411,000			
	,, 4.	1,[illegible]00	18,000	380,000			
	,, 5.	1,[illegible]00	15,000	346,000			
	,, 6.	1,[illegible]00	16,000	490,000			
	,, 8.	1,[illegible]00	18,000	328,000			
	,, 10.	1,[illegible]00	11,500	361,000			
	,, 14.	1,[illegible]00	9,000	418,000			
	,, 19.	1,[illegible]00	18,000	423,000			
	,, 23.	2,[illegible]00	10,500	342,000			
	,, 25.	2,[illegible]00	9,000	341,000			
Case 3— M. G., 25. Anæmia due to Metrorrhagia.	Nov. 7.	1,675,000	...	[illegible]			
	,, 13.	2,210,000	...	625,000			
	,, 17.	2,280,000	9,300	960,000			
	,, 24.*	1,920,000	6,500	784,000			
	Dec. 1.	2,160,000	12,000	658,000			
	,, 8.	3,190,000	11,000	506,000			
	,, 15.	3,756,000	8,000	527,000			
	,, 21.	3,644,000	7,000	384,000			
	,, 29.	4,616,000	7,000	316,000			
	Jan. 17.*	2,855,000	7,500	518,000			
	,, 30.*	2,858,000	12,000	462,000			
Case 4— M. W., 27, F. Anæmia due to Metrorrhagia.	Sept. 8.	1,921,000	9,000	286,000			
	,, 13.	2,447,000	8,000	289,000			
	,, 28.	3,091,000	4,000	280,000			
Case 5— J. M., 27, F. Hæmatemesis.	Mar. 14.	2,636,000	8,000	396,000			
	,, 16.	2,582,000	7,500	341,000			
	,, 21.	2,754,000	9,000	409,000			
	,, 27.	2,664,000	7,500	424,000			
	Apr. 1.	3,121,000	7,000	312,000			
Case 6— J. H., 55, M. Hæmaturia.	Feb. 27.	2,816,000	10,500	314,000			
Case 7— B. M., 67, M. Bleeding Hæmorrhoids.	Mar. 4.	2,601,000	6,500	322,000			
Case 8— J. M., 43, M. Hæmatemesis.	Mar. 15.	4,050,000	7,500	366,000			
Case 9— J. B., 20, M. Hæmatemesis.	...	2,068,000	18,000	Increased.			

* After renewed hæmorrhage.

variety of form and size. In Case 3, for example, in which the anæmia was due to numerous hæmorrhages extending over a period of several weeks, scarcely any corpuscles were of normal appearance when the anæmia was at its height, the size of the corpuscles varying from 3·5 μ to 10 μ, and irregular forms being exceedingly abundant. Especially striking was the presence of many small poikilocytes of great thinness and delicacy, but with the elastic properties characteristic of red corpuscles. Filamentous forms were also seen, which were probably the detached processes of the larger poikilocytes (fig. 7). In such conditions the red corpuscles do not form rouleaux, but lie scattered over the microscopic field, and they often show a tendency to early crenation. As recovery takes place, these poikilocytes gradually disappear from the blood, yet some may be found even when the number of red corpuscles has reached 4,000,000 per c.mm. The number of poikilocytes depends upon the duration and intensity of the anæmia and is not proportioned to its intensity alone.

Nucleated red corpuscles may appear in the blood if the anæmia is intense. They were present in Cases 1 and 2; in the former in considerable numbers. Their diameter is about 8 μ, they are perfectly circular, and possess a single round nucleus about 4 μ in diameter, which generally shows a well-marked reticular structure. These are the "normoblasts" of Ehrlich (fig. 8). Their presence would appear to depend, to some extent at least, upon the degree of the anæmia, as they were found in the two cases in which the anæmia was greatest. I cannot yet say whether they afford any aid in prognosis, though it is noticeable that the patient in whose blood they were most numerous made a good recovery.

The number of leucocytes is increased after large hæmorrhages, absolutely as well as relatively. In Case 1, for example, their proportion to red corpuscles became as high as 1:47. The multinucleated leucocytes are especially increased in number, so that their proportion to the uninucleated forms may exceed double the normal. Intermediate forms between the two varieties are also more numerous. After a few days both the number of leucocytes and the proportion of the different forms become normal. The coarsely granular corpuscles are not increased in number.

The blood-plates increase in number after hæmorrhage, often to an extraordinary extent. In Case 3 their number was increased threefold, and their proportion to red corpuscles rose to 1 : 2·7. As recovery takes places their number diminishes. The increase appears to be greater in cases of long-standing anæmia due to repeated hæmorrhages than in cases of equal intensity produced acutely. In only one case was their size increased, but very few exceeded 3·5 μ in diameter.

I obtained the impression from these cases that the increase in the number of leucocytes after hæmorrhage was a more passing phenomenon than that of the blood-plates—probably related to the alteration in the volume of the blood caused by the hæmorrhage. The increase of the blood-plates occurred later, and was to be associated either with the process of regeneration of the blood or with its impoverished condition. This impression was confirmed by the results of experiments.

Case 1 illustrates how great a quantity of blood may be lost without fatal result, if there be sufficient time between the hæmorrhages to allow the fluid part of the blood to be restored. The patient in this case lost four-fifths of his red corpuscles within ten days, yet he recovered rapidly, and some weeks later, when I had an opportunity of examining him, the condition of his blood was almost normal. The rate of restoration of the red corpuscles is, in favourable conditions, a comparatively rapid one. A million corpuscles per c.mm. may be added in the course of a week. In some cases, however, recovery is very slow, and the anæmia may even increase for some time after the loss of blood (Case 2). Cases have also been recorded by others in which a progressive anæmia with a fatal result has followed severe losses of blood.

PERNICIOUS ANÆMIA.

I have placed for convenience in this table, in addition to true cases of pernicious anæmia, a few cases whose nature is doubtful. These latter were examples neither of typical pernicious anæmia nor of chlorosis, and the alterations in the blood also were of somewhat indefinite character.

It will be seen from the annexed table that in six cases of pernicious anæmia the number of red corpuscles fell below a

TABLE II.—*Pernicious Anæmia, &c.*

	Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.	Poikilocytes.	Nucleated Red Corpuscles.
Case 10— J. C., 54, M. Pernicious Anæmia.	Feb. 21.	1,404,000	3,500	31,000	1: ·81	Very numerous.	None.
	" 28.	1,560,000	3,500	74,000	1: ·74	"	"
	Mar. 6.	1,636,000	5,000	92,000	1: ·8	"	"
	" 14.	1,614,000	3,500	117,000	1: ·79	"	"
	" 27.	1,601,000	2,500	124,000	1: ·8	Numerous.	"
	Aug. 10.	425,000	1,500	8,000	1: ·42	"	"
Case 11— J. G., 60, M. Pernicious Anæmia.	July 14.	790,000	3,000	18,000	1: ·59	Very numerous.	Few.
	" 21.	717,000	5,000	15,000	...	"	...
	" 28.	701,000	2,000	8,000	1: ·59	"	"
Case 12— D. M'G., 62, M. Pernicious Anæmia.	Feb. 2.	812,500	2,500	11,000	1:1·1	Very numerous.	None.
	" 17.	961,000	1,000	13,000	1:1·1	"	"
	Mar. 6.	1,465,000	1,000	23,000	1:1·3	"	"
Case 13— D. R., 55, M. Pernicious Anæmia.	Feb. 8.	909,280	2,000	44,000	1: ·25	Numerous.	Fairly numerous.
	" 20.	1,522,500	1,500	68,000	1: ·4	"	"
	" 25.	1,923,000	2,000	76,000	1: ·5	"	"
	Mar. 13.	2,359,000	3,000	173,000	1:1	Few.	Very few.
	Apr. 9.	2,436,000	2,500	262,400	1:1·2	Very few.	None.
Case 14— J. B., 51, M. Pernicious Anæmia.	Mar. 13.	785,000	1,500	9,000	1: ·7	Very numerous.	None.
	" 24.	481,250	1,000	7,000	1: ·4	"	Numerous.
	" 29.	575,000	2,500	33,000	1: ·54	"	"
	Apr. 8.	940,000	3,000	54,000	1:1·2	"	Very few.
Case 15— J. F., 26, F. Pernicious Anæmia.	Dec. 10.	622,000	1,000	13,000	1:1·3	Numerous.	None.
Case 16— J. J., 55, M. Pernicious Anæmia.	Jan. 15.	1,206,000	7,000	101,000	1:1·8	Numerous.	None.
	" 24.	1,150,000	3,500	88,000	1:1·9	"	"
Case 17— W. C., 6, M. Anæmia with Purpuric Eruption.	Dec. 25.	1,281,000	1,500	33,000	1: ·22	None.	None.
Case 18— T. M'R., 45, F. Pernicious Anæmia. (?)	Dec. 15.	1,720,000	1,000	105,000	1:1·5	Numerous.	None.
	Jan. 21.	2,940,000	5,500	146,000	1:1·3	Less numerous.	...
	" 28.	3,108,000	4,500	144,000	...	"	...
Case 19— M. M., 36, F. Pernicious Anæmia. (Cured.) (?)	Jan. 17.	3,388,000	2,500	402,000	1: ·55	Very few.	None.
	" 19.	3,286,000	3,500	380,000	1: ·63	"	"
Case 20— S. W., 55, M. Pernicious Anæmia, much improved.	Nov. 11.	2,623,000	4,500	102,000	...	Very few	None.
	" 27.	2,601,000	9,000	212,000	1:1·9	"	"
	Dec. 6	2,745,000	9,000	232,000	...	"	"
	" 14.	2,628,000	7,500	152,000	...	"	"
	Jan. 16.	2,875,000	6,000	138,000	1:2·2	"	"
Case 21— J. R., 18, F. Anæmia of doubtful nature, great enlargement of Spleen.	Dec. 6.	1,925,000	2,500	86,000	...	Few.	None.
	" 19.	1,895,000	2,000	74,000	...	"	"
	" 21.	1,954,000	3,000	56,000	1: ·3	"	"
	" 23.	2,070,000	3,000	104,000	...	"	"
	" 25.	2,122,000	2,500	81,000	...	"	"
	" 29.	2,056,000	1,500	74,000	...	"	"
	Jan. 16.	2,001,000	1,000	91,000	1: ·25	"	"

million per c.mm., in two below half a million. Five of these patients were males over fifty years of age. In four cases a fatal result occurred, post-mortem examinations were obtained in three (Cases 10, 12, 15), and in all of these the characteristic change in the liver described by various observers[1] was found.

The following is a summary of the changes which I have found in true cases of pernicious anæmia. Variations in the size of the red corpuscles are very abundant, the extremes may be said to be generally 3 μ and 12 μ (*i.e.*, of the circular forms). Small corpuscles, about 4 μ, are frequently seen, sometimes being convex on both sides, but very often presenting a deep concavity on one side like a little bell. I have never seen any of these corpuscles deeply coloured, as Eichorst describes. Megalocytes are generally present in large numbers. Poikilocytes also are generally numerous, but their number is not always proportional to the severity of the anæmia (*v.* Case 10, where they were less numerous immediately before the death of the patient than several months before). Many of the poikilocytes are in the form of large oval corpuscles, whose long axis sometimes measures 16 μ (fig. 5). A peculiar condition was found in the case of a patient who was believed to have suffered from pernicious anæmia, the number of the red corpuscles being at one time considerably under a million per c.mm. The red corpuscles were practically all of regular size and shape, but were considerably larger than normal, having a diameter of 9 μ. Measurements on two separate occasions gave the same results. I have not seen such a condition described before, though Gram, in a series of elaborate measurements, has found that in many cases of pernicious anæmia, the *average* diameter is over 8 μ.

The corpuscles are generally well coloured, and the hæmoglobin is proportionately less diminished than the number of the corpuscles.

Nucleated red corpuscles may be present. I found them in three cases, but in one of these they were very scanty. They may be larger than ordinary red corpuscles, are very rarely smaller, and are sometimes of irregular shape. In this point my results completely confirm those of Ehrlich. They generally have a single nucleus, but sometimes two or three of unequal

[1] *Vide* W. Hunter, *Op. cit.*

size. The nuclei have rarely the typical reticular structure. Generally they appear somewhat homogeneous, and sometimes they are broken up into fragments to a greater or less extent (*v.* figs. 9, 10). In one case (14) there were a number of small dark granules in some of the red corpuscles, both of the ordinary and of the nucleated variety. In films stained with methyl-blue they appeared almost black, but I was not able to determine whether they were derived from a degenerated nucleus or from the hæmoglobin. They appeared in the blood after a marked fall in the number of the red corpuscles, and were seen on two separate occasions.

I cannot yet speak definitely regarding the significance of the presence of nucleated red corpuscles in the blood in pernicious anæmia, but it is significant that the two patients in whose blood they were most numerous ultimately recovered, while in the case of most extreme anæmia they were absent immediately before death. Ehrlich[1] also records a case in which they were absent before death, when the red corpuscles had fallen to 213,360 per c.mm. There is, therefore, reason in his supposition that their presence indicates that the bone-marrow is still producing red corpuscles.

The leucocytes are generally diminished in number, sometimes proportionately even more than the red corpuscles. Eichorst and others have found the same condition. The decrease is mainly on the part of the large multinucleated leucocytes, so that these are often less numerous than the uninucleated forms, this change being most marked in Case 13, where the latter were four times as numerous as the former. In Ehrlich's case just mentioned, practically the same condition was present, and Hayem[2] also notes the preponderance of the small form of leucocytes in such cases, but without giving actual figures. The uninucleated corpuscles are chiefly of the small size, the large uninucleated corpuscles and the intermediate forms being few in number. There is, therefore, in this condition a diminished production of multinucleated leucocytes. Coarsely granular corpuscles are generally very scanty.

I have found the blood-plates invariably diminished in

[1] Ehrlich, *Charité Annal.*, 1888, xiii. p. 303.
[2] Hayem, *Compt. rend.*, 1880, p. 225.

number, and when the anæmia was extreme they were very scanty indeed, whole fields of the microscope being found in which none were visible. This result confirms the statements of Riess, Eichorst, Osler, and Halla.[1] In cases where the condition improves their number increases, sometimes more rapidly than the number of the red corpuscles (*v.* Cases 10 and 13).

It will be seen from the above cases, that where the anæmia is intense, the blood has certain characteristics which differ very markedly from those found in severe traumatic anæmia. In the other cases in the table whose clinical nature was doubtful (Cases 17 to 20), some of the above changes were generally present, *e.g.*, often the leucocytes were diminished in number, especially the multinucleated forms, often the blood-plates were few, but the blood did not present the typical condition. It is unnecessary to give all the details.

EXPLANATION OF PLATE IX.

Fig. 1. Leucocytes from normal human blood; *a*, uninucleated corpuscles; *b*, intermediate form; *c*, typical multinucleated corpuscles; *d*, eosinophile corpuscle; *e*, corpuscle with granules stained deeply by methyl-blue. Dry preparations; *a*, *b*, *c*, *e*, stained with methyl-blue; *d*, stained with watery solution of eosine.

Fig. 2. Leucocytes from the blood in a case of suppuration, showing great increase in the proportion of the multinucleated forms. (The number of leucocytes was 36,500 per c.mm. "Proportion A" was 1 : 13·5.) Dry preparation. Methyl-blue.

Fig. 3. Leucocytes from leucocythæmic blood, showing great variety of forms; *a*, large corpuscles with nuclei somewhat faintly stained, not normally present in the blood; *b*, corpuscles with granules deeply stained by methyl-blue. Dry preparation. Methyl-blue.

Fig. 4. Leucocytes from another case of leucocythæmia in which the uninucleated corpuscles were almost exclusively increased. Dry preparation. Methyl-blue.

Fig. 5. Poikilocytes from a case in pernicious anæmia. Dry preparation. Fuchsin.

Fig. 6. Red corpuscles from fresh blood in a case of chlorosis, showing irregular forms.

Fig. 7. Red corpuscles from fresh blood of a case of traumatic anæmia, showing many small poikilocytes.

[1] Halla, *Fortschr. d. Med.*, 1884, p. 479.

Fig. 8. Typical nucleated red corpuscles ("normoblasts") from the blood in a case of traumatic anæmia; *a*, ordinary red corpuscle. Dry preparation. Methyl-blue and fuchsin.

Fig. 9. Nucleated red corpuscles from the blood of a case of pernicious anæmia, of somewhat irregular shape, and with irregularly disposed nucleus. Dry preparation. Methyl-blue.

Fig. 10. Nucleated red corpuscles showing fragmentation, and breaking down of the nucleus, from a case of pernicious anæmia; *a*, do., containing more than one nucleus, from a case of leucocythæmia. Dry preparations. Methyl-blue and fuchsin.

In all these figures the magnifying power is about 1000 diameters.

(*To be continued.*)

A THEORY TO EXPLAIN THE EVOLUTION OF WARM-BLOODED VERTEBRATES. By W. Hale White, M.D., *Physician to Guy's Hospital.*

As far as I am aware, no explanations have been offered of the mode in which in the process of evolution cold-blooded animals became warm-blooded. Yet, when we reflect upon the enormous amount of energy which must be necessary to maintain the temperature of, for example, a Polar Bear, the change is one of the most important in evolution.

I would suggest that the key to the explanation is that in vertebrates, at least, cold-blooded animals are aquatic and warm-blooded animals are primarily terrestrial.

The temperature of the air at the same spot may vary as much as 30° Fahrenheit in a few hours, and the variation for the year is often 100° or more. The temperature of water is much more constant, for, in the first place, in cold weather it cools so slowly that often it never reaches freezing-point, and it never falls below that at which the ice on it forms; and when the thaw comes, it is not suddenly warmed, but remains at freezing-point till the ice has all gone, therefore its temperature is constant and not extremely cold for weeks together in the winter, and as spring approaches it rises very slowly in consequence of the great specific heat of water. The following figures show the comparative uniformity of the temperature of the sea which is coldest in Europe in February, when it is nearly 50° F. at the entrance to the English Channel, 45° F. round the Irish coast, and 40° F. along the east coast of Great Britain, so that there is only a difference of 8° or 9° F. about the British Isles. In August, the hottest month, the sea round Ireland is only 10° F. warmer than in the winter. Off the south-east of England the annual variation is nearly 20° F., and off the rest of the east coast it is about 15° F.

Then also it must be remembered that variations in the temperature of the sea are chiefly on the surface. Deeper

down the temperature is much more constant. In rivers and lakes there are many local variations due to the depth of the water, the presence of springs, &c.

It is therefore clear that while terrestrial animals are subjected to extreme and often sudden changes of temperature, aquatic animals, on the other hand, are never subjected to such extremes, for the annual changes in the temperature of their surrounding medium are slight; they are also very gradual, and may to a certain extent be avoided by alteration of locality.

Aquatic animals preceded terrestrial in their order of appearance on the globe, and therefore terrestrial animals must have been evolved from aquatic. The change must have been a very severe one, for the various vital and chemical processes, which had hitherto been carried on in a medium whose temperature was not liable to sudden alterations, and whose variations in temperature were slight, and whose inhabitants, by shifting their locality, could keep the temperature of their surroundings fairly uniform, had now to be performed in a medium liable to great and sudden variations in temperature, and which does not present the same opportunities to its inhabitants of maintaining a constant temperature of their surrounding medium by alteration of locality. Naturally at first it would not be possible for the creatures to become completely terrestrial, for they would not be able to withstand the alterations in the temperature of their medium for a whole year, therefore we should expect first to meet with amphibians, and that is precisely what happens.

In the struggle for existence, those creatures who could, however slightly, diminish the fluctuations of their own temperature in spite of the great variations in that of their surrounding medium, would stand the best chance of survival, for then their various functions, which had previously been accustomed to a surrounding medium of a fairly constant temperature without sudden variations, would best be able to be performed. Thus we should gradually have evolved from amphibians completely terrestrial animals, who could at least keep their own temperature as uniform as that of the water in which their ancestors lived. But the process would not stop here, for, with such great and

sudden variations in temperature as are common in the air, it would obviously be a great advantage if all the vital and chemical processes of the body could always go on at a more uniform temperature than that of water, and thus we should gradually have evolved that perfection of warm-bloodedness which we see in man, in whom the temperature does not vary more than 1° C. and in many individuals not that, in spite of enormous alterations in the temperature of the air.

If this view is correct it must follow that (*a*) aquatic animals are cold blooded, (*b*) terrestrial animals are warm-blooded, but that those which are lowest in the scale are less completely warm-blooded than those which are highest; (*c*) that the embryos and young of warm-blooded animals are less perfectly warm-blooded than the adults; (*d*) that only terrestrial animals should possess an apparatus for maintaining the bodily heat uniform; (*e*) that there should be some special explanation of the occurrence of aquatic warm-blooded animals.

(*a*) That the temperature of fish rises and falls with that of the water in which they live is well known. More than a hundred years ago John Hunter[1] made many experiments on this point. He took a living and a dead tench, a living and a dead eel, they all received heat equally fast, and when they were put into the cold they all cooled at the same rate. An eel, whose temperature was 44° F. (6°·5 C.) which was nearly that of the atmosphere, was put into water at 65° F. (18°·5 C.) for fifteen minutes, and then its temperature was found to be that of the water. Another eel, whose temperature was 37° F. (3° C.) was put into a cold mixture, and its temperature sank to 31° F. (– 0·5° C.), but it was not killed. Dr Davy found that the temperature of fish in water at 72° F. (22°·5 C.) was 74° F. (23°·5 C.). Carpenter states that two species of fish have a temperature higher than that of the water in which they live. The thunny is one, and the other is the closely allied bonito, precisely which variety is not stated, whose temperature is 99° F. (37°·3 C.), and that of the sea in which it lives is 80°·5 F. (31° C.). It is curious that both these fish are red-blooded. It would be very valuable if some one living on the shores of the Mediterranean would investigate this alleged warm-bloodedness of the thunny, and at the same time

[1] *Phil. Trans.*, 1778, "On the Heat of Animals and Vegetables."

note its habits, to see if, owing to any annual migrations, or if from any other cause, the temperature of the sea in which it lives is very variable.

It is also well known that amphibians, as a class, are cold-blooded. Hunter took a frog and put the thermometer into its stomach; the temperature was 44° F. (6°·5 C.). The animal was placed in a cold mixture, and its temperature quickly fell to 31° F. (– ·5° C.). It is stated in *Todd's Cyclopædia* that the temperature of frogs follows to a very great extent that of the atmosphere, between 32° and 77° F., differing at no time by more than a degree or two. In a few amphibians their temperature is above that of the surrounding medium,—thus Max Fürbringer[1] says that the temperature of Proteus may be 9° F. (5° C.) above that of its surrounding medium, and that of some species of Rana may be raised 7° F. (4° C.); but he says that these rises are very transitory and variable. Possibly these slightly raised temperatures in amphibians are to be looked upon as the dawn of warm-bloodedness in animals, which are partially terrestrial. Occasionally, if the air be very hot, the temperature of a frog may be a little below it; still, within moderate limits, the animal's temperature mounts with that of the air.

(*b*) If it is true that terrestial animals are warm-blooded, but that those which are lowest on the scale are least so, we ought to find that reptiles are very imperfectly warm-blooded. These creatures are generally classed as cold-blooded, but this is not altogether true. Carpenter says that to a limited extent they have the power of maintaining their temperature above that of the air, and other text-books speak of the temperature of the blood of reptiles as being slightly above that of the air. Max Fürbringer states that the temperature of Testudo may be 7° F. (4° C.). that of Lacerta 12° F. (7° C.). that of Anguis 14° F. (8° C.), and that of Viper 11° F. (6°·5 C.) above that of the atmosphere. It is well known that during the breeding season the temperature of the female python may be very much higher than that of the air, but even during these months the creature's temperature is not uniform, so that its warm-bloodedness is by no means perfect. Valenciennes, taking observations during eight

[1] *Untersuchungen zur Morphologie und Systematik der Vögel*, Amsterdam, 1888.

weeks, found that the animal's temperature was usually 38° F. (21° C.) above that of the air, its maximum bodily temperature being 105°·8 F. (41° C.). and its minimum 82°·4 F. (28° C.). Forbes, during five weeks' observations on a female Indian python, found its temperature to be 17° F. (9°·5 C.) above that of the air; its maximum was 91°·4 F. (33° C.), and its minimum 86° F. (30° C.). Hunter took a healthy viper, introduced a thermometer into its stomach and anus, it stood at 68° F. (20° C.), the temperature of the air being 58° F. (14°·5 C.), or 10 degrees Fahrenheit lower. The animal was put into a cool mixture and its temperature fell. Hunter especially calls attention to the fact that it became colder much more slowly than did amphibians and fish when a similar experiment was performed upon them. Also, the temperature of some reptiles may be below that of the air, if this be high,—thus Dr Davy found that when the air was at 90° F. (32°·5 C.) the temperature of a tortoise was 85° F. (29°·5 C.).

We thus see that there are many instances of reptiles being imperfectly warm-blooded, and that when they are cooled their temperature falls more slowly than does that of aquatic animals.

Passing now to birds, a great stride has been made, they are much more perfectly warm-blooded. Dr Davy is quoted in *Todd's Cyclopædia* as having made observations "on fifteen species in different orders. The mean temperature of the air was 79° F. (26°·1 C), between the extremes of 59° F. (15° C.) and 88°·75 F. (31°·5 C.). The temperature of the subjects of the experiments offered a mean of 107°·85 F. (42°·1 C.). The superior limit being 111° F. (43°·9 C.), the inferior 99° F. (37°·2 C.). The temperature of birds, therefore, presents a scale much more extensive than that of man and the Mammalia, amounting to as many as 12° F. (6°·7 C.)." The fact that, although birds are warm-blooded, their temperature may vary considerably is shown by the following experiments of Dr Davy. In the month of February the mean temperature of some sparrows was found to be 105° F. (40°·5 C.), in April 108° F. (42°·5 C.), in July 111° F. (44° C.). Thus in six months we have a range of 6 degrees Fahrenheit. Max Fürbringer also states that birds may have a daily variation of their temperature of

from 4° to 6° F. He considers that the higher the birds are in the scale, and the smaller their size, the higher will be their temperature. Hunter took the rectal temperature of several cocks and hens, in some it was 103° F. (39°·4 C.), in others 103°·5 F. (39°·7 C.), and in others 104° F. (40° C.). As far as our information goes, it appears that for the whole of the class of birds the extremes of temperature are from 100° F. (37°·7 C.) to 112° F. (44°·5 C.); the usual limits are from 104°·5 F. (40°·3 C.) to 109°·5 F. (43° C.). We thus see that birds are very completely warm-blooded, but that there are considerable variations not only often in the same individuals, but also among different species.

Mammals are warm-blooded, but by no means equally. In man the temperature in health ranges between 98°·4 F. (37° C.) and 99°·5 F. (37°·6 C.), so that we shall be well within the mark if we say that the range is less than a degree Centigrade and more than a degree Fahrenheit. Thus the temperature of man is very constant, and this is remarkable when we remember the great varieties of external temperature to which he is subjected.

Dr Washbourn and I have made observations on the rectal temperature of two healthy Rhesus monkeys, and it will be seen that there is a range of 6° F. (3°·5 C.) or, in other words, the range is four or five times as great as in man.

MONKEY I.

Nov. 4.	4	P.M.	102°·4	Nov. 7.	12	A.M.	101°·4
"	12	"	99·6	"	6	P.M.	101·6
Nov. 5.	11½	A.M.	104	"	11¾	"	102
"	6¼	P.M.	101·8	Nov. 8.	11	A.M.	103·4
"	11¼	"	98·4	"	2¾	P.M.	102
Nov. 6.	11¼	A.M.	103·4	"	10¾	"	101·6
"	4½	P.M.	101·6	Nov. 9.	10¼	A.M.	100·4
"	11¾	"	98·6	"	4¼	P.M.	101·8
Nov. 7.	8½	A.M.	102·4	"	8¼	"	102·6

MONKEY II.

Dec. 5.	11½	A.M.	100°·4	Dec. 8.	1	P.M.	100°·2
" 6.	11	"	102·2	"	4½	"	100

I have elsewhere [1] stated that the normal rectal temperature of a rabbit is between 101° and 103° F. (38°·4 and 39°·6 C.), and this is true for the great majority of these animals, but occasionally one meets with a temperature a degree Fahrenheit above this, and occasionally with one a degree Fahrenheit below, and yet the animal seems well. Reichert [2] has made a very complete series of observations on the normal rectal temperature of dogs, and he finds from observations made upon fifty-five dogs that the lowest rectal temperature of any animal was 100°·6 F. (38°·1 C.), and the highest 104°·5 F. (40°·27 C.) giving a range of 4 degrees Fahrenheit. In each case the temperature was taken under the same conditions, as regards time of day, meals, &c., and it was always taken again at the end of an hour. Sometimes it was the same, but most often it had varied. The greatest rise during the hour was 1°·17 F. (0°·65 C.), and the greatest fall during the hour was 1°·71 F. (0°·95 C.). In a second series of experiments, in which few animals were used but the observations extended over some days, in one animal the temperature varied during five days between 103°·3 F. (39°·73 C.) and 100°·45 F. (38°·05 C.).

Of course it is quite possible that these variations in the temperature of monkeys, rabbits, and dogs may be due to slight exciting causes, still when we remember how carefully the human temperature has been observed, and how few, comparatively speaking, are the observations on these animals, it is clear that the temperature of monkeys, rabbits, and dogs is much less constant than that of man. It is true that in *Todd's Cyclopædia of Anatomy and Physiology* it is stated that the extent of the variation of the temperature in man is 6° F. (3°·3 C.), but we know now that this is far too wide a range. In these observations the human temperature was taken in the mouth, where it is far from constant.

It is well known that most mammals are very completely warm-blooded, for they have the power of maintaining their high temperature uniform,—as we have just seen is the case with man, monkeys, rabbits, and dogs,—however variable that of the air. Captain Parry found that when the temperature of

[1] *Journal of Physiology*, vol. xi. No. 1.
[2] *University of Pennsylvania Med. Mag.*, Feb. 1890 and April 1890.

the air was −21° F. (−29°·4 C.) the temperature of the white hare was 101° F. (38°·3 C.); with the temperature of the air at −27° F. (−32°·8 C.) the temperature of the wolf was 105° F. (40°·5 C.); and when the temperature of the air was −31° F. (−35° C.) that of the arctic fox was 107° F. (41°·5 C.). Many observations have shown also that mammals maintain their temperature nearly constant, however high that of the air. Among all but the extremely low mammals, the range of temperature is from 94° F. (34°·5 C.) in *Cervus alces* to 107° F. (41°·5 C.) in the wolf and the arctic fox. But it is extremely important to notice that just those two mammals which are lowest in the mammalian scale are feebly warm-blooded, for the temperature of *Echidna hystrix* is only 82°·4 F. (28° C.), and that of the *Ornithorhynchus* is 76°·5 F. (24°·8 C.).

At first sight hybernating animals appear to be an exception to the fact that terrestrial animals are warm-blooded, for during the state of hybernation the animal's temperature rises and falls with that of the surrounding medium. I have often convinced myself of the truth of this in the case of dormice, and Marshall Hall showed that is true in the case of bats. But hybernating animals are really more an instance of the exception proving the rule, for while they are awake they maintain a constant high temperature—in dormice about 97° F. (36° C.)—independent of the temperature of the air; and while they are hybernating almost all the functions of the body—motion, digestion, eating, reproduction—are in abeyance, respiration is not visible, hardly any change takes place in the air of a closed cage containing hybernating animals, the circulation is very slow, and sensation and volition are absent. Now, my original contention was, that terrestrial animals became warm-blooded, because, if cold blooded, their functions could not have gone on with air as a surrounding medium; and hybernating animals teach us that when a terrestrial animal ceases temporarily to be warm-blooded its functions almost cease. Directly the dormouse becomes warm-blooded its functions become active, and the rapidity with which it becomes warm-blooded is most remarkable. I have often waked a dormouse in a state of hybernation at the temperature of the atmosphere in winter—from 35° to 45° F. (2° to 8° C.)—by bringing it into a room at 60° F. (16° C.). It

has taken about two hours for the animal's temperature to rise to 60° F., but within ten minutes of its attaining that point the creature's temperature has reached 97° F. (36° C.), it is breathing fast, its heart is rapid, it is wide awake, running about, and anxious for food.

Our knowledge of the habits of hybernating animals is not complete; but, as far as we know, all hybernating animals inhabit countries in which the food on which they live is difficult to obtain in winter. Therefore, as these creatures, not having wings, cannot migrate like birds, they would die in the winter of starvation unless they hybernated, for they would not be able to get sufficient food to maintain their temperature and the functions of their body. This is borne out by the fact that the most perfect hybernating animal is a bat, and these creatures live on insects, which, of course, cannot be obtained at all during winter. Hedgehogs and dormice can get a little food during winter, and they do not hybernate so completely as the bat.

The material at our disposal is not sufficient for any precise scale to be drawn up, but I think I have shown that the lowest terrestrial vertebrates—reptiles—are least warm-blooded, that Man, the highest terrestrial vertebrate, is the most perfectly warm-blooded; that the warm-bloodedness of the mammals immediately below man, although very complete, is less perfect than that of man; that the temperature of Ornithorhynchus and Echidna, the very lowest animals in the mammalian scale, is not much above that of the atmosphere; that birds are warm-blooded; and that, although we have very few observations upon them, the range of their temperature is 12° F., while among mammals, which have been much more extensively observed, if we exclude such exceptional animals as Ornithorhynchus and Echidna, the range is only 13° F., so that it appears extremely probable that, if more observations were taken, they would show that the ordinary species of birds are not quite so perfectly warm-blooded as the ordinary species of mammals.

(*c*) The fœtus *in utero*, in at least the early months of its life, is a cold-blooded animal, and it is only gradually that it becomes warm-blooded. It is well known that the greatest care must be exercised to keep prematurely born children

warm. The axillary temperature of a seven months' child was found to be 89°·6 F. (32° C.). Even at birth at full time the human child has not so high a temperature as the adult, the mean being only 94°·5 F. (34°·75 C.). Every physician also knows that the temperature of children, especially very young children, is not nearly so constant as that of adults. Thus the young of man are neither so warm-blooded nor so perfectly warm-blooded as adults.

W. F. Edwards, in *Todd's Cyclopædia*, found that, among newly-born rats, guinea-pigs, puppies, and rabbits, their temperature, even when they were lying next to their mother, was from 2° to 5° F. (1° to 3° C.) below hers; and with young birds the difference in temperature was often 3° to 9° F. (2° to 5° C.) between them and their mother. But the almost complete cold-bloodedness of newly-born puppies was very well shown when they were removed from their mother. The temperature of the air was 55°·5 F. (13° C.). The temperature of the puppies was 98°·4 F. (36°·7 C.); in successive periods of ten minutes each it declined the following amounts, expressed in degrees Centigrade:—0°·63, 1°·12, 1°·38, 1°·25, 1°·29, 0°·87, 1°·63, 0°·25, 1°·0; in thirty-five minutes the temperature declined further 1°·25 C.; in thirty-five minutes more it fell 3°·12 C.; in thirty minutes more 2°·50 C.; in twenty-five minutes more 1°·25 C.; in thirty minutes more 1°·25 C.; so that in four hours it had fallen 33° F., or 18°·2 C., and the animals could not maintain their temperature much above that of the atmosphere. Many similar experiments were done on other puppies, kittens, and young rabbits, and the results were the same. Some kittens cooled 36° F. (20° C.) in three hours and a half.

The temperature of the young of many species of birds, when taken out of the nest, falls very rapidly. Thus a young sparrow a few days old lost in an hour and seven minutes 21°·5 F. (12° C.). All young birds and mammals are not so completely cold-blooded as these animals, but that is probably because they are born more fully developed; for it is just those which at birth are most advanced that are least cold-blooded. Hunter found that the temperature of an egg was in its interior 99°·5 F. (37°·6 C.), but the temperature under the hen from which it had just been removed was 104° F. (40° C.).

Thus there appears no doubt but that the embryos and the young of warm-blooded animals are much less warm-blooded than the adults.

(*d*) Warm-blooded animals possess a mechanism for producing heat, a mechanism for preventing its loss, and a mechanism for maintaining such a balance between the loss and production that the temperature is uniform. Our knowledge of the details of the last is too elementary for this to be the place to discuss it.

Other observers and myself[1] have brought forward evidence to show that the corpus striatum presides over the production of heat. As far as the text-books on comparative anatomy give us any information on the subject, it appears that the corpus striatum is small in fishes and amphibians, is larger in reptiles, and becomes much larger in birds. In mammals, as is well known, it is very large. We thus see that, roughly speaking, the corpus striatum is smallest in cold-blooded animals and largest in warm-blooded. Further observations are required; perhaps it will be found that the reptilian corpus striatum is largest in those reptiles which are most warm-blooded, and that the mammalian is smallest in those mammals which are least warm-blooded, such as the Ornithorhynchus. Its large size in birds is interesting when we remember their high temperature.

The chief means of preventing loss of heat are hair and feathers. Hair and feathers are limited entirely to warm-blooded animals, so, if my theory be correct, when aquatic animals become terrestrial, and therefore warm-blooded, any who had any arrangement of skin which would enable them to retain more heat than their companions would stand the best chance in the struggle for existence, and thus gradually hair and feathers would be developed. Unless when aquatic animals became terrestrial it was necessary that they should become warm-blooded, it is difficult to see the reason for the extensive development of such excellent non-conductors as hair and feathers.

As far as our evidence goes, then, it shows that those organs which have to do with the maintenance of warm-bloodedness are best developed in, and some are confined to, terrestrial animals.

[1] *Jour. of Phys.*, vol. xi. No. 1, and *Brit. Med. Jour.*, March 14, 1891.

(*e*) Aquatic birds and mammals present really no difficulty to my theory, for they are comparatively recently derived from terrestrial forms, and therefore we should expect them to be warm-blooded, and their enormous layers of fat and very thick skins serve to prevent their losing heat; but possibly they in course of time may become cold-blooded. It is curious that, in a list of the temperature of mammals given by Max Fürbringer, out of the four with the lowest temperatures three are aquatic, viz., *Phocæna communis*, 96° F. (35°·6 C.); *Balæna mysticetus*, 101°·8 F. (38°·8 C.); Manatus, 101°·9 F. (38°·9 C.) the temperatures above these being—Lepus, 104° F. (40° C.); Capra, 104° F. (40° C.); Lupus, 104°·9 F. (40°·5 C.); Ovis, 104°·9 F. (40°·5 C.); and Vulpes, 106°·4 F. (41°·5 C.).

It seems to me, therefore, for all these reasons, a probable theory that the cause of the appearance of warm-blooded animals was the change from aquatic to terrestrial habits, just as that change caused the appearance of an air-breathing apparatus.

This theory does not explain why the temperature is high, but only why it is uniform in warm-blooded animals. We must suppose that a temperature of somewhere between 94° F. (34°·5 C.), and 112° F. (44°·5 C.) is the temperature at which the various vital and chemical processes of the body are best performed, and that it has at last been attained by natural selection.

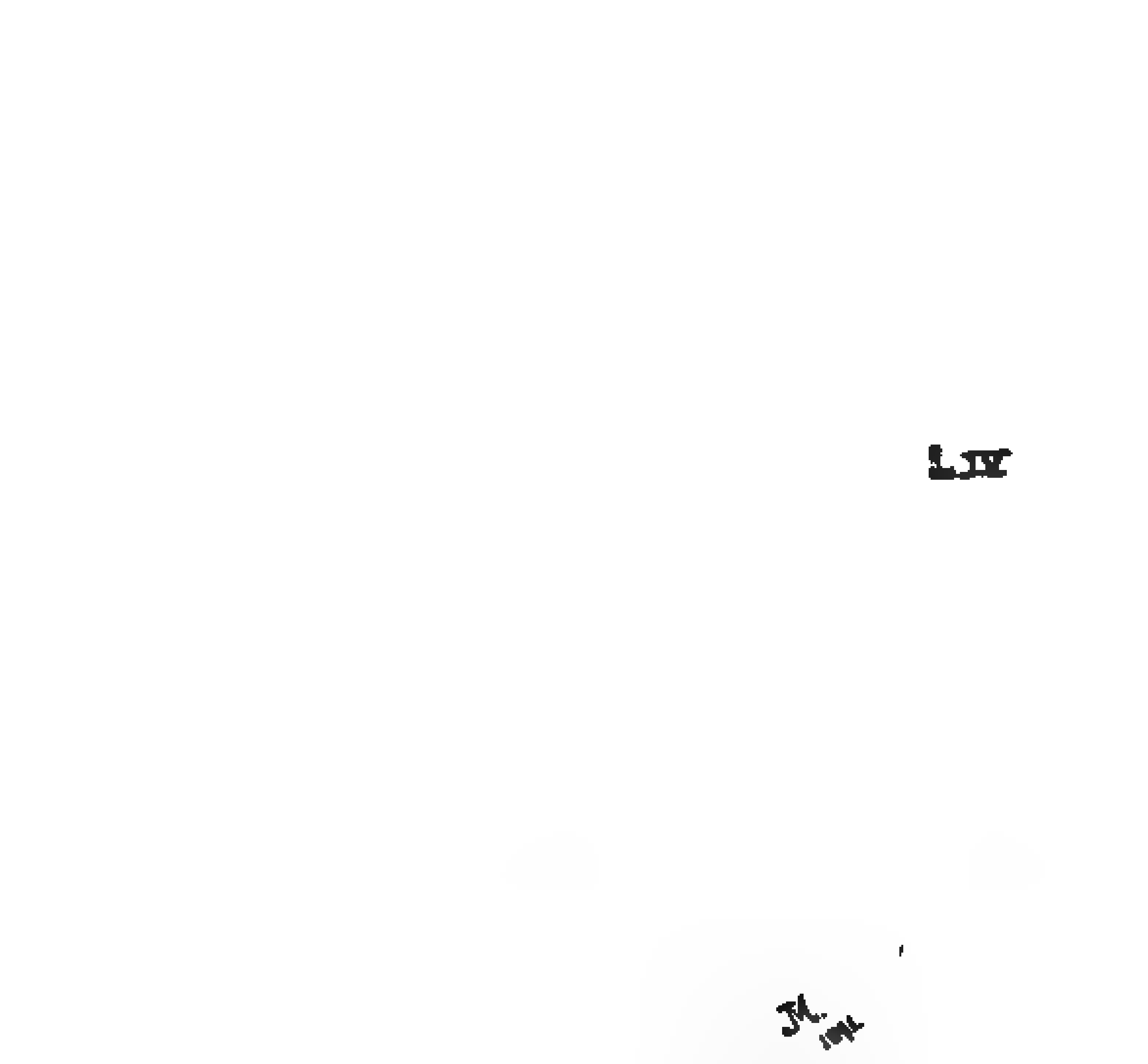
If it be asked why aquatic animals have not a high temperature, it must be remembered that the demand upon the energy of an aquatic animal, if it had to constantly maintain its temperature above that of the water, would be enormous.

PERSISTENCE OF THE NOTOCHORD IN THE HUMAN SUBJECT. By JAMES MUSGROVE, M.D., M.R.C.S., *Demonstrator of Anatomy, Edinburgh University.*

WHATEVER difference of opinion may exist among histologists concerning the origin and function of the notochord, there can be little doubt that, after the development of the bodies of the vertebræ around this central axis, its remains may still be found at birth, and even in the adult subject. Not only does this column of cells tend to persist, but an actual increase in its size may take place—in one animal, opposite the body of the vertebra; in another, corresponding to the intervertebral disc. We may recognise, indeed, three modes in which the notochord may persist. In the first, as found in reptiles, birds, and amphibia, the notochord disappears from the intervertebral spaces, owing probably to the development of synovial cavities; whilst in the bodies of the vertebræ its remains may be recognised. In some mammals, on the other hand, which illustrate the second mode of persistence, the notochord shows a dilatation in the intervertebral disc, and is continued through the body of the vertebra as a slender rod, with two smaller dilatations, one between each epiphyseal plate and the centrum. In the third form, found in osseous fishes, the intervertebral dilatations of the notochord take place to such an extent that the bodies of the vertebræ are markedly amphicœlous in character, the concavities being joined by a short canal filled by the constricted part of the notochord. In the human subject the arrangement is similar to that found in other mammals, the persistence being most evident in the intervertebral disc, although it has also been recognised as a slender rod through the body of the vertebra. This is the usual arrangement.

In a subject which I recently examined in the dissecting-room at the University of Edinburgh, I found in one of the lumbar vertebræ a condition reproducing the characters of the osseous fishes. On making a transverse section through the

middle of the body of the fourth lumbar vertebra, there was seen in the centre of the bone a core of unossified tissue, resembling in appearance the tissue of an intervertebral disc. The section bore a striking resemblance to the vertebra of a human fœtus at the eighth week,[1] figured by Kölliker, where the notochord is seen in the centre of the body of the vertebra, surrounded on all sides by cartilage. This core of unossified tissue had a diameter of 15 millimetres from side to side, and 12 millimetres



from before backwards. Immediately surrounding the central core was an ill-defined cartilaginous-looking layer 2 millimetres in thickness, and surrounding this again the cancellous tissue of the vetebral body. The cancellous tissue in the greater part of the section resembled that of a normal vertebra, but the bone at the hinder part, between the core and the posterior common ligament, was more fibrous, and less perfectly

[1] Reproduced in Schäfer's "Embryology," part 1, vol. i. of *Quain's Anatomy*, 1890.

RESEARCH INTO THE CHEMICAL PROCESSES IN THE SMALL INTESTINE OF MAN. By ALLAN MACFADYEN, M.D. (Edin.), M. NENCKI, M.D., and N. SIEBER, M.D. (PLATE X.)[1].

(From the Physiological Chemical Laboratory, University of Berne.)

WE possess a considerable number of analyses of the bile, and of the pancreatic and intestinal secretions. Of the latter there are, besides the older analyses of Frerichs, Zander, and others, several of more recent date since Villa improved Thiry's method of establishing an intestinal fistula. There exist, also, numerous experiments made *in vitro* as to the action of these secretions upon the food. But since the early and, for that time, excellent research of Tiedemann and Gmelin, only a few and incomplete observations have been made with regard to the processes as they occur *in vivo*. These observations were made mostly upon animals; a few upon human beings with intestinal fistula.

Through the courtesy of Professor Kocher, it was our good fortune to be able to investigate, during a considerable period, the chemical processes in the small intestine of Man. In the surgical clinic of the University of Berne a woman was this year (1890) operated upon for strangulated hernia. On account of gangrene of the strangulated portion of intestine, and acute inflammation of the surrounding tissues, the gangrenous portion had to be removed, and an anus præternaturalis established. The strangulated and excised piece was exactly that portion of the ileum which opens into the cæcum. As a result the food-mass, after it had been subjected to the action of the mucosa of the whole small intestine, flowed out of the mouth of the fistula instead of passing into the large intestine. We had, therefore, the opportunity of studying, as far as we know for the first time in Man, the chemical processes in the *whole* of the small intestine. In the cases of fistula in the small intestine already recorded, it

[1] Professor Nencki desires to acknowledge in this place the financial support afforded him by a grant from the "Elizabeth Thompson Science Fund" in Boston, and to express his thanks to the Board of Trustees of this admirable Foundation.

Fig.3b.

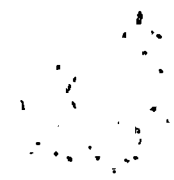


Fig.4 a

Fig.4 b

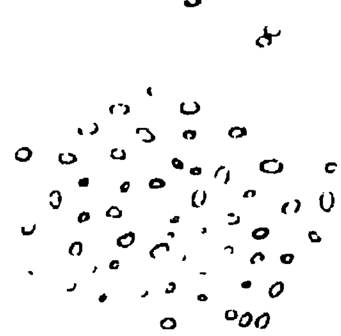


Fig.5 b.

Fig.7.

Macfadyen.

was always uncertain in what portion of the same the opening was, and to what degree and extent the food-mass might have been further altered in the portion of intestine below the fistula, An exact knowledge of the processes of digestion can be best obtained from the living subject, and it is of great importance to investigate separately the changes undergone by the food in the individual and anatomically different sections of the digestive tract. The knowledge thereby gained would be invaluable in the treatment of intestinal affections. It was considerations such as these that prompted us to undertake the following investigation. We avail ourselves of this opportunity to thank Professor Kocher for directing our attention to the case, and to express our indebtedness to his assistant, Dr Lanz, for his kind help and the attention he paid to our wishes with regard to the patient.

The patient, Magdalene Spycher, was a peasant woman, from Könitz, near Berne, sixty-two years old, thin, and of medium height. Her weight on admission was only 40 kilogrammes. She was received into the surgical wards on the 16th May 1890, and was operated upon on the same day. The subcutaneous cellular tissue was already partly necrotic; the hernia sac, with the portion of omentum contained therein, completely necrotic. The protruding coil of intestine was gangrenous. There was an oblong perforation in the intestine, and it was evident that the protruding coils were cæcum and ileum. On account of the intense inflammation, it would have been dangerous to stitch the large and small intestine together. Accordingly the gangrenous portions were removed, and an anus præternaturalis established. The portion of small intestine excised was about 10 centimetres long, the portion of cæcum about 3 centimetres long. The wound healed rapidly; and on the following day the patient felt better. There were no symptoms of peritonitis, and the temperature remained normal. A quantity of pulpy excrement was discharged from the fistula in the ileum. Three days later (the 19th) a hard stool passed per anum. From the ileum the discharge was diarrhœic; and tinct. opii was administered. The patient thereafter had a good appetite, and felt well. On the 4th of June, the discharge from the ileum, being again diarrhœic, decoctum rhatanhiæ was administered, and the diarrhœa ceased. On the 5th of June the patient was put upon a diet chosen by herself. It was weighed daily, and consisted of the following items :—

Bread, . . .	260 grms.	Peptone (Kemmerich),	20 grms.
Meat, . . .	100 „	Sugar, . . .	60 „
with two eggs.		Milk, . . .	100 „
Barley gruel, . .	200 „	Bouillon, . .	1050 „

This diet was given during the day as follows :—

Morning, 7 o'clock.—350 grms. coffee infusion, 50 grms. milk, one milk-roll, and 10 grms. sugar.

Morning, 10 o'clock.—350 grms. bouillon, one egg, and half a milk-roll.

Noon, 12 o'clock.—360 grms. bouillon, 10 grms. peptone, 100 grms. minced meat, 200 grms. barley gruel, half a milk-roll, and 10 grms. sugar.

Afternoon, 3 o'clock.—350 grms. tea infusion, 50 grms. milk, 10 grms. sugar, and half a milk-roll.

Evening, 6 o'clock.—350 grms. bouillon, 10 grms. peptone, one egg, and half a milk-roll.

As beverage during the day the patient received 200 grms. wine, 200 grms. water, and 20 grms. sugar; during the night, 150 grms. "grog," with 10 grms. sugar. (The "grog" consisted of rum, water, and sugar.)

A short indiarubber tube was inserted into the opening of the fistula. This tube was cleaned and washed out with water daily. The contents of the intestine were collected in a flask, and handed over to us for investigation. The urine passed in 24 hours was investigated daily, and the urea estimated by Hüfner's method. During June and July the contents of the small intestine were collected as discharged, and investigated by us in different directions. We will first describe their external appearance, and then proceed to the examination of the individual constituents.

The amount of matter passing out of the ileum into the cæcum depends upon the consistence of the food-mass. With the above diet, in which nitrogenous food predominated, the intestinal contents were of thin consistence, and contained on an average 5 per cent. of solids and 95 per cent. water. At times they had the appearance of diarrhœic stools, and constipating drugs were administered. When the patient received a vegetable diet the discharge became more consistent, and contained on an average 10 per cent. of solids. Repeated experiments confirmed this observation. After carefully collecting as much as possible of the discharge from the fistula, we found that the maximum amount of the thin discharge in 24 hours was 550 grms., with 4·9 per cent. of solids. The maximum amount of the more consistent and porridge-like discharge was 232 grms., with 11·23 per cent. of solids. The passage of the food-mass into the large intestine is a constant one. During the night it sinks to a minimum, no doubt because the patient broke her fast five times during the day, and at night received only a stimulant. The evacuation took place without the patient being conscious of the act. Two series of control experiments were made in order to determine when the undigested portion of the food passes into the large intestine, and the length of time the food-mass remains in the small intestine. In the first case the patient was given boiled, unmashed green peas, as we noticed that they were discharged from the fistula unchanged; the second test used was salol, which is decomposed in the intestine, and salicylic acid set free. On the 10th July the patient received at midday (12 o'clock), instead of the barley gruel, 200 grms. boiled green peas. The first discharge

of peas from the fistula took place at 5.30 P.M., the last at 11 A.M. on the next day. They were undigested. The pea diet had, however, to be suspended, as the patient complained of loss of appetite.

On the 28th July she was given, at 10.30 A.M., 2 grms. Salol. Up to 12.15 the intestinal contents were collected as discharged, in all 30 grms. They were filtered, the filtrate acidified with a few drops of hydrochloric acid, and extracted with ether. The ether was then evaporated, and to the remainder were added a few drops of water and a drop of ferric chloride. The result was negative; no salicylic acid was present. The intestinal contents collected between 12.15 and 1.15 P.M. (62 grms.) were treated in the same manner. With ferric chloride they gave a distinct violet colour. The discharge between 1.15 and 3.15 P.M. (33 grms.) contained the largest amount of salicylic acid. We obtained from the ethereal extract a few milligrammes of crystalline salicylic acid. The acidity of the discharge was normal; estimated as acetic acid it was 0·0924 per cent. From this stage onwards the amount of salicylic acid diminished. The last distinct reaction was obtained from the intestinal contents discharged between 12.30 A.M. and 2.30 A.M. The discharge between 2.30 A.M. and 4.30 A.M. (17 grms.) gave no reaction. These experiments were repeated at a much later date, viz., on the 15th and 16th October. At the same time we endeavoured to estimate the amount of the hourly discharge into the cæcum. For this purpose the intestinal contents were collected every two hours in weighed glass flasks.

On the 16th October the patient received at 7 A.M. coffee, a milk-roll, and 125 grammes boiled green peas, and at 9 A.M. 2 grammes of Salol. The following table gives the weight of the discharge, as collected every two hours:—

	7–9	9–11	11–1	1–3	3–5	5–7	7–9	9–11	11–1	1–3	3–5	5–7	
15th October,	117 gr.	49	9	49	118	27	64	27	18	10	12	15	515 grms. in 24 hours.
16th October,	0	62	42	55	56	89	40	14	7	21	2	2	390 grms. in 24 hours.

On the above dates the intestinal contents were of thin consistence. The first discharge of peas came at 9.15 A.M., *i.e.*, after an interval of 2¼ hours. There was a fresh discharge at 3 P.M. and again between 7 and 9 P.M. The discharge then ceased. After the administration of Salol (9 A.M.), salicylic acid was detected in the intestinal contents discharged between 11 A.M. and 1 P.M. The last traces were found in the portions collected between 5 and 7 P.M. The experiments with Salol tend to prove that the food-mass reaches the large intestine at the earliest three hours after a meal. The experiments with green peas did not give such consistent results. In the one case the peas first appeared after an interval of 5¼ hours, in the other after 2¼ hours. In the first experiments with Salol the evacuation of the same lasted about 14 hours, in the second only about 9 hours.

The last peas were discharged after 23 hours and 14 hours respectively. These variations depend upon the varying *consistence* of the food-mass, as determined by the amount of absorption taking place in the intestine The shorter the period that the food remains in the intestine the larger is the amount of water it contains. The discharge we examined in July was thick and porridge-like, and contained 9·3 per cent. solids. The discharge on the 15th October was semifluid, and the amount of solids only 4·8 per cent.

Whilst the patient continued to receive the above-mentioned diet, in which proteids predominated, the discharge from the fistula was yellow or yellowish-brown in colour, due to bilirubin. It was generally almost odourless, and had a slightly burning taste. The faint odour it possessed reminded one of volatile fatty acids. More rarely a feebly putrefactive odour was detected, as of indol. The discharge was usually thin and semifluid—at times thick and porridge-like. In the latter case the average amount of solids was 10 per cent.

Plate X. fig. 1, reproduces the microscopical appearance of the intestinal contents during proteid diet; one can easily recognise numerous striped muscular fibres tinged yellow by the bile pigments, detritus, pigment granules, and amorphous albumen. Also mucin, bile-acid flocculi, vegetable fibres, and numerous bacteria.

Fig. 2 depicts the intestinal contents during a diet in which carbohydrates (mashed peas) predominated. The preparation is tinged with iodine. Starch granules prevail, and are mostly stained red, indicating their transformation into amylodextrin. There are also numerous bacteria.

The numerous experiments we have made upon our patient, and also upon animals, prove that bacteria are constantly present in the fresh intestinal contents.

The normal reaction of the food-mass passing into the cæcum was acid. We tested the discharge from the fistula during five months, from the middle of May to the middle of October. During June and July the reaction was tested daily, and only on two occasions was it neutral, viz., after a diet of mashed peas. The filtered intestinal contents were also titrated with normal alkali solution. Litmus or cyanin was used as indicator. The average degree of acidity, calculated as acetic acid, was 1 per 1000. We will return to this point later on.

The intestinal contents, after filtration from the morphotic and undissolved constituents, contained the following substances in solution:—albumen, coagulable by heat; mucin, peptones, starch-derivatives, such as dextrin and dextrose; ordinary lactic acid and the active paralactic acid; small quantities of volatile fatty acids, chiefly acetic; bile acids

and bilirubin. The discharge became green when exposed to the air. This is due to the transformation of bilirubin into biliverdin.

When the degree of acidity of the filtrate was considerably higher than 1 per 1000—1·5 per 1000—the addition of acetic acid caused no precipitate, or at most a faint cloudiness. By lower degrees of acidity, a flocculent precipitate of mucin ensued. On account of the acidity, the albumen in the filtrate coagulates simply on heating. By higher degrees of acidity the filtrate had to be neutralised with an alkali before the albumen could be precipitated by heat.

The following extracts from our laboratory notebook will serve to give an approximate representation of the percentage amount of albumen, sugar, and acid in the intestinal contents:—

Discharge on 16th June.—Peasoup-consistence, in filtrate albumen, mucin, and sugar. The albumen coagulates on heating. Acidity, calculated as acetic acid, 0·116 per cent.

24th June.—Amount received from hospital = 290 grammes. Peasoup consistence. Reaction, acid. Acidity = 0·191 per cent. Sugar (Fehling's method) = 1·47 per cent.

25th June.—Discharge semifluid. Reaction, acid. Acidity = 0·171 per cent. Sugar = 0·31 per cent. Coagulable albumen = 0·698 per cent.

29th June.—Discharge semifluid, odour of volatile fatty acids. Reaction, strongly acid.

Microscopically: Numerous muscular fibres, visible also microscopically as bile-tinged clots; numerous bacteria non-motile, probably from the high acidity of the discharge.

Sugar = 4·75 per cent. Acidity = 0·207 per cent. The filtrate, on adding acetic acid, gave no mucin precipitate. On heating, the albumen first coagulated after adding ammonia.

30th June.—Discharge more consistent—an odour of fatty acids. Acidity = 0·091 per cent.

1st July.—Amount received = 316 grammes. Odour of fatty acids; semifluid. Acidity = 0·114 per cent.

July 2.—Acidity = 0·154 per cent.; Albumen = 0·45 per cent.

July 3.—Amount = 323 grammes; acidity = 0·122 per cent.; albumen = 0·814 per cent.; sugar = 1·53 per cent.

July 4.—Amount = 228 grammes; peasoup consistence; an odour of fatty acids; acidity = 0·041 per cent.; sugar = 1·29 per cent.

A portion was reserved for the estimation of nitrogen, oxygen, and dry remainder—2·3586 grammes were dried at 110° C. to a constant weight in a small platinum vessel; remainder = 0·1935 grm. and solid remainder = 8·2 per cent. 0·1935 grm. of the solid remainder yielded 9·8 c.c. N. gas at 22° C. and 713 mm. barometric pressure. This is equivalent to 5·39 per cent. nitrogen in the dry solid remainder, or 0·44 per cent. nitrogen in the fresh intestinal contents.

July 7.—Discharge semifluid; faintly acid and almost odourless; a marked peptone reaction; sugar = 1·58 per cent.

2·9276 grms. dried at 110° C. yielded 0·1937 grm. = 6·52 per cent. dry substance. After combustion the amount of nitrogen gas was 12·4 c.c. at 21° C. and 707 mm. barometric pressure. The percentage amount of nitrogen in the dry remainder was therefore 6·78 per cent.; in the fresh intestinal contents 0·44 per cent.

From the 10th to the 18th July the patient was given at noon boiled peas instead of barley gruel. On the first day she complained of loss of appetite, so the peas were given to her mashed—140 grammes daily.

Discharge on July 10.—Two portions were received from the hospital: (1) 120 grammes semifluid discharge, which was passed after the usual diet of meat and barley gruel. The reaction was acid. Sugar = 1·8 per cent. (2) 83 grammes thick consistent discharge, passed at 5.30 P.M., after the patient partook of boiled green peas at 12 o'clock noon. It was filled with swollen undigested peas. The reaction was acid.

July 11.—Discharge porridge-like. Acid reaction. Microscopically were seen numerous cells filled with starch granules, more rarely muscular fibres. A portion of the discharge was semifluid. The whole was mixed with water and filtered. In the filtrate were sugar and albumen. On adding acetic acid, no cloudy precipitate.

July 12.—The discharge was thinner and more fluid. Numerous cells containing starch were present. Acidity = 0·163 per cent.

July 13.—Reaction acid; odour, faintly putrefactive. In the filtrate was 0·95 per cent. sugar.

July 14.—Discharge thickish; acid, with a faint putrefactive odour. A portion was dried for an elementary analysis.

3·3624 grammes dried in a platinum vessel gave 0·2982 grm. remainder. Dry remainder therefore = 8·87 per cent. The nitrogen estimation gave 12·6 c.c. N gas at 22° C., and 713 mm. bar. pressure, *i.e.*, 4·49 per cent. N in the dry remainder, or 0·398 per cent. N in the fresh moist substance.

Further, 3·4518 grms. moist substance gave 0·3062 grm. dry remainder. The combustion in an oxygen current with CuO, gave 0·4987 grammes CO_2, and 0·167 grm. H_2O = 44·41 per cent. C. and 6·05 per cent. H.

The remainder of the discharge, as well as that of the 14th, 15th, and 16th July, was dried and utilised for an ash estimation.

July 18.—Discharge thickish, reaction acid. It contained numerous muscular fibres, and was the first passed after stopping the pea diet.

July 19.—Discharge thickish and consistent, and contained many muscular fibres. The filtrate was acid, and contained only traces of sugar and albumen. The albumen was first precipitated after adding ammonia. Acetic acid gave no cloudy precipitate.

July 23.—Discharge consistent and acid—sugar = 0·47 per cent. The solid remainder was estimated, as well as the substances soluble in ether. 2·453 grammes gave 0·2754 grm. dry remainder = 11·23 per

cent. Further, 5·1505 grammes gave 0·5785 grms. dry remainder and contained 0·047 grm., *i.e.*, 8·12 per cent. of matter soluble in ether.

July 27.—Amount of discharge received = 385 grms. It was semifluid, and contained 0·937 per cent. sugar. Acidity = 0·154 per cent.

July 30.—Amount was 307 grms. with 9·12 per cent. solid remainder.

July 31.—Amount = 269 grm. with 9·29 per cent. solid remainder. The discharge on the last two days was used for an ash estimation.

The figures we obtained show that the amount of dissolved albumen which passes with the food-mass into the cæcum is less than 1 per cent. The amount of sugar is subject to greater variations,—from 0·3 per cent. to 4·75 per cent. The maximum amount of sugar in the discharge was found on the 29th of June, and on that day the acidity also reached its maximum, viz., 0·21 per cent. The intestinal contents were watery and diarrhœic in character. We always found that the amount of sugar and acid was higher in the semifluid than in the more consistent and porridge-like discharge. In the latter case the absorption was clearly greater.

After a diet of meat, eggs, peptone, and barley gruel, the amount of unabsorbed nitrogen, *i.e.*, albumen, was equal to 5·39 and 6·78 per cent. of the dry remainder. When mashed peas were substituted for barley gruel, the most of the starchy matter passed unchanged through the small intestine, and the amount of nitrogen was 4·49 per cent. This nitrogen was almost entirely derived from albumen.

On adding caustic soda to the intestinal contents no smell of ammonia was detected. On heating there was a faint odour of ammonia and trimethylamine. As will be shown further on we found neither leucin nor tyrosin in the discharge. If we calculate the nitrogen as albumen, by multiplying with the factor 6·25, then 5·39 grms. nitrogen = 32·68 grms. albumen; 6·78 grms. N = 42·37 grms. albumen and 4·49 grms. N = 28·0 grms. albumen. According to this calculation, 30–42 per cent. of the dry remainder consisted of proteids. If we add thereto 8·5 per cent. for inorganic salts, and an equal amount for fat and substances soluble in ether, about 40 per cent. of the dry remainder would consist of carbohydrates and substances only soluble in alcohol. With a diet of mashed peas the amount of carbohydrates would be about 55 per cent.

One fact is especially worthy of notice, viz., our observation that the contents of the small intestine in its entire length have an *acid* reaction. In animals, and in cases of fistula in the small intestine of man, this observation has repeatedly been made. Tiedemann and Gmelin[1] state that in fasting animals the fluid contained in the small intestine reddened litmus paper, and that this acid reaction diminished towards the lower part of the intestine. The same authors confirm the fact, first observed by Prevost and Le Royer,[2] that the food-mass in the first two stomachs of ruminants has an *alkaline* reaction. In the third stomach the contents were thinner and reddened litmus paper, similarly also in the rennet stomach, and in the whole of the small intestine to the end of the ileum, where the acidity completely disappeared. In the Carnivora, according to Meissner, the contents of the duodenum have always an acid reaction. Ewald states that in his patient, with a fistula probably in the lower part of the small intestine, the reaction of the fresh discharge immediately tested was neutral or faintly acid, but at no time alkaline. We may mention here that the intestinal contents should first be filtered before testing the reaction or estimating the acidity. This removes the deeply bile-stained constituents of the food-mass, which tend to mask the reaction. It often occurred that whilst the reaction of the fresh discharge seemed to us doubtful, the filtrate had a distinctly acid reaction. The causes of the acid reaction of the contents of the small intestine down to the cæcum, are undoubtedly organic acids, and chief amongst these acetic acid. The lactic acids formed in the digestive tract are neutralised by the alkali supplied by the mucosa. The neutralisation of the hydrochloric acid of the gastric juice takes place in the upper part of the intestine. We repeatedly tested the filtered intestinal contents with the methyl-violet and the Ginsburg reagent for free hydrochloric acid. The results were always negative.

All analyses of the intestinal juice consistently show that this secretion contains sodic carbonate, and it was interesting to note in our patient that the mucous coat of the ileum reacted alkaline, the food-mass covering it acid. Incidentally we observed

[1] Berzelius' *Jahresbericht*, vol. vii., 1828.
[2] Berzelius' *Jahresbericht*, vol. v., 1826.

that the alkaline reaction of the colon's mucosa was always more intense than that of the ileums. The statement found in most handbooks that the chyme is already neutralised in the upper part of the small intestine, and generally reacts alkaline in the lower part, is not correct. The alkaline reaction first begins in the large intestine, after the food has passed through the ileo-cæcal valve. Through the continuous neutralisation of the chyme on the alkaline mucous coat of the small intestine a precipitate results. This precipitate consists of mucin, bile acids, fat, cholesterin, and a neutralisation precipitate of albumen. This precipitate adheres to the mucous coat, and this circumstance may well be of importance for the absorption of fats.

When we mixed the filtered discharge from the fistula with a 5 per cent. solution of glycocholate of soda, a precipitate did not immediately occur; but after half an hour all the glycocholic acid was precipitated.

The fact that the food-mass in the entire length of the small intestine has an acid reaction, and that, consequently, the pancreatic digestion of proteids, carbohydrates, and fats takes place in an acid medium, should be taken into account in future artificial digestion experiments. It has been already shown by one of us[1] that by *acid* reaction the pancreas splits into their components, fats and acid ethers or "esters." Experiments, to be immediately described, show further, that the acid reaction of the food-mass has a distinctly inimical influence on those bacteria which only flourish in neutral or alkaline nutrient media.

It was of especial interest to discover the share the numerous bacteria present in the small intestine take in the decomposition of the food. The acid reaction of the food-mass and its faintly and not always putrefactive odour, were already against the supposition of any active decomposition by their agency. Still it was possible that, whilst on account of deficient oxygen the final products of putrefaction—such as indol, skatol, phenol, volatile fatty acids, &c.—would not be found, the first decomposition products of the proteids (the amido acids) might be present.[2]

[1] *Archiv für. Exper. Pathol. u. Pharmakol.*, vol. xx. p. 375, 1885.
[2] *Wiener Akad. Berichte*, 1889.

To investigate this point we proceeded as follows:—The intestinal contents daily received from the hospital were at once mixed with oxalic acid; the amount of acid added was 5 per cent. The discharge was collected for several days, and then distilled, about a kilogramme at one time. A small flask connected with the condenser collected any volatile products carried over with the water vapour. The gases developed during the distillation passed from this flask into a glass-bulb apparatus filled with a 3 per cent. solution of the cyanide of mercury. This solution would absorb sulphuretted hydrogen and methylmercaptan if present. In this manner we manipulated more than two kilogrammes of the intestinal contents. As regards gases, with the exception of CO_2, only traces of H_2S were present. The amount was so small that it was only after long standing that any precipitate of sulphide of mercury took place in the solution. The first portions of the watery distillate, tested with picric and hydrochloric acids, or nitrous acid, gave neither an indol or skatol reaction. Bromine gave no precipitate, and only Millon's reagent produced a faint pink tinge in the distillate after heating. Thus the final products of the putrefactive decomposition of albumen failed entirely, or were only present in traces. This agrees with Ewald's results. He found in the intestinal contents of his patient neither phenol, indol, or skatol. That a minimal amount of indol was present was proved by the odour of the discharge, and the presence of indoxyl in the urine. These two tests are much more delicate than picric acid or nitrous acid. We detected indigo in the urine of the patient on different days, after the large intestine had been empty for more than a month. On adding to the urine an equal volume of chlorine containing hydrochloric acid and shaking with some chloroform, the latter acquired a distinctly blue colour, due to the dissolved indigo. The addition of chloride of calcium is to be avoided, as it destroys any traces of indigo which may be present. From two kilogrammes of the intestinal contents we obtained about 1·5 gramme of volatile fatty acids, consisting almost entirely of acetic acid. The soda salt was precipitated with a solution of nitrate of silver, and the silver salt analysed. Result = 64·1 per cent. Ag. The formula $C_2H_3O_2$ Ag corresponds to 64·67 per cent. Ag.

The remainder in the retort, after distilling over the volatile products, was concentrated on the water-bath to a syrupy consistence, and then extracted with ether. After distilling off the ether there remained a small quantity of an acid syrupy fluid. This acid fluid was miscible in all proportions with water, and gave negative reactions for phenylpropionic, skatolacetic, and aromatic oxyacids. It was boiled with an excess of zinc hydroxide, filtered, and the filtrate concentrated on the water-bath till crystallisation began. The first zinc salt which crystallised out of the cooled solution resembled microscopically the lactate of zinc. It was recrystallised out of water, and analysed. 0·2253 gram. of the salt dried in the air lost, at 110° C., 0·0411 grm. in weight = 18·24 per cent.; and 0·1842 grm. of the dry salt after combustion gave 0·0612 grm. ZnO

= 26·66 per cent. zinc. The salt was therefore the ordinary lactate of zinc, with three molecules of water of crystallisation. The formula $(C_3H_5O_3)_2Zn3H_2O$ requires a loss of 18·18 per cent. in weight through water of crystallisation. The mother liquid of these crystals, on being further concentrated, deposited a second zinc salt, easily soluble in water. This led us to suppose that the optically active paralactic acid might also be present. By repeated crystallisation in water we were able also to obtain this easily soluble salt in a pure state. After drying in the air, 0·2008 grm. lost at 110° C. 0·0257 grm. weight = 12·88 per cent.; and 0·1751 grm. of the dry salt gave on combustion 0·0583 grm. ZnO = 26·72 per cent. zinc. The paralactate of zinc contains 12·89 per cent. water of crystallisation. Two kilogrammes of the intestinal contents yielded approximately three grammes of the lactic acids, and each of the two acids was present in about equal amount.

The complete absence of the fermentation products of albumens prompted us to search for the next hydration products of proteids, viz., leucin and tyrosin. On four successive days the fresh intestinal contents were mixed with three times their volume of absolute alcohol, then filtered and the alcohol distilled off. The remainder in the retort, after evaporation, showed no crystalline remainder after long standing. The portion insoluble in alcohol was next extracted with warm water and filtered. Lime and phosphoric acid were removed by adding a small quantity of carbonate of ammonia, and the liquid condensed to syrup consistence. After long standing neither leucin nor tyrosin were detected. The syrupy mass was then extracted with hot alcohol, and the filtrate condensed on the water-bath. Here also, even after two months, no crystallisation occurred. The syrupy mass consisted chiefly of peptones, mixed with sugar and bile acids.

We now followed another method. A larger quantity of the intestinal contents was extracted with ether, in order to remove the bile constituents and fats. 233 grammes of the dry intestinal contents were treated with ether in an extraction apparatus. Over night well-formed rhombic crystals of bilirubin crystallised out of the ethereal solution. The faintly-red solution contained no urobilin, and, examined spectroscopically, gave no absorption bands between *b* and *F*. The addition of an alcoholic-ammoniacal zinc chloride solution did not produce the slightest fluorescence. This observation is interesting, because it shows us that the seat of the reduction processes, especially the metamorphosis of bilirubin into urobilin, is not in the small but in the large intestine. As ether did not completely remove the bile pigment, the powder was once more extracted with chloroform. In this case also only bilirubin was found, and no urobilin. We next extracted with alcohol, and evaporated the alcoholic solution. As it still contained gummy bile substances which gave a precipitate in water, the remainder was boiled with water and the watery extract evaporated. After standing for several days a few rhombic needles formed, which might easily be mistaken for tyrosin. They were freed as much as possible from the mother

liquid. They were easily soluble in water, and gave all the reactions of succinic acid. The weight of the remainder, after complete extraction with ether, chloroform, and alcohol, was 201 grammes. Thus the dry intestinal contents yielded 13·3 per cent. of soluble substances. The watery extract, condensed to a syrup, gave neither leucin nor tyrosin. It consisted chiefly of sugar and peptones. We will not positively assert that leucin and tyrosin are not formed out of proteids in the small intestines by the action of the pancreatic juice. If, however, these two substances do arise in the small intestine, their amount must be very small and their absorption very rapid.

Our investigations show that in the small intestine the proteids are not, or only in very small quantity, decomposed by the bacteria. The faintly acid reaction of the intestinal contents suggested, however, the possibility of a decomposition of the carbohydrates through their agency. The presence of lactic and acetic acid also favoured this assumption. Microscopical preparations of the discharge abundantly proved that micro-organisms were present in great number, and our next task was to isolate the microbes in pure cultures, with a view of testing their action on proteids and carbohydrates. The opening of the fistula was always kept aseptic, and the woman was in a private room and separated from the other patients. We were, therefore, able to carry out our bacteriological investigations under favourable conditions, and to make the inoculations in a quiet atmosphere. The patient by coughing was able to move the food-mass downwards, and to eject a portion from the mouth of the fistula. With a sterilised platinum loop it was easy to reach the lumen of the intestine, and to remove portions of the contents before they came in contact with the air. At times the discharge was so abundant that we could collect it directly in a sterile glass vessel, which was applied closely to the mouth of the fistula. The further investigation was carried out as follows.

Coloured and uncoloured preparations of the fresh discharge were examined microscopically, in order to obtain a preliminary notion of the bacterial forms present, and their relative number. Portions of the intestinal contents were well mixed with liquefied gelatine (10 per cent.) and agar (1·5 per cent.). From these Esmarch "roll-plates" were made in 5 to 6 dilutions. The gelatine and a portion of the agar-plates were kept at 18° to

20° C.—the remaining agar-plates were placed in an incubator at 37° to 38° C.

Portions of the discharge were also mixed with a weakly alkaline meat broth, and after one to two days gelatine and agar-plates made therefrom.

Anaerobic plates were also made. The agar and gelatine after inoculation were poured out in small glass vessels, and covered with a layer of gelatine or liquid paraffin. Esmarch "roll-plates" were also covered with sterile paraffin or olive oil. Nutrient solutions, containing glycerine, grape-sugar, and bile respectively, were also used. We will return to these later on. We made inoculations twice whilst the patient received a diet in which proteids preponderated, and once whilst the diet consisted in great part of carbohydrates (mashed peas).

I. *The Cultures after a Meat Diet.*

The coloured and uncoloured microscopical preparations contained a great number of bacteria. Amongst these were isolated forms, which remained uncoloured, or only faintly stained, by the pigments (methylene blue and phenolfuchsin). It was not easy to distinguish the different forms from one another. We could, however, recognise with certainty four forms of bacilli and two species of micrococci—in all six. Examined in meat broth in a glass cell, some of the bacteria were motile. The majority were non-motile, and seemed to us to be in an enfeebled condition. The gelatine plates were next examined. The first dilutions were quickly liquefied, and it was difficult to separate the different colonies from one another. From the more dilute plates we could, however, isolate the different colonies. The liquefying bacteria were present on all the plates, and as they grew more quickly they were first isolated. They were bacilli, and in "stabcultures" produced a funnel-shaped liquefaction of the gelatine. The agar-plates and those made from meat broth rendered it easier to isolate the more slowly-growing forms. We examined the plates so long as there was any apparent growth. By these methods we isolated eight bacterial forms, three of which were distinguished by their constant presence on the plates. These were:—

1. A bacillus, which quickly liquefies gelatine, and which we will call the *bacillus liquefaciens ilei.*
2. A short rod-shaped bacillus, resembling in appearance the bacillus coli commune.
3. An oval bacterium, which did not liquefy gelatine.

In addition to these predominating forms, the following microbes were isolated from scattered colonies :—

4. A bacillus of ellipsoid shape.
5. A large, plump bacillus.
6. A streptococcus, non-liquefying.
7. Yeast fungi.
8. A mould fungus, resembling morphologically, and probably identical with, the oidium lactis.

It is worthy of notice that not only schizomycetes, but also yeast and mould fungi, were isolated from the contents of the small intestine, and that they still retained their vitality after having been subjected to the action of the gastric and intestinal juices. The three first-mentioned and the yeast fungi were the only forms present in number; the others were first isolated after many examinations of the plates. Putrefactive bacteria were not isolated. On the anaerobic gelatine and agar plates we found three forms, which, however, in their morphological appearance and growth in different nutrient media, corresponded to forms already isolated aerobically. They were :—

1. A non-liquefying short rod bacillus.
2. A non-liquefying oval bacterium.
3. A streptococcus.

The first two were the prevailing forms. All three were facultative anaerobic bacteria. Amongst the bacteria isolated we found no obligatory anaerobic forms.

II. *The Cultures after a Diet mainly Carbohydrate.*

The methods were the same as in the former case. The microscopic preparations again contained numerous bacteria. The coloured preparations contained also forms which took up the pigment very feebly or not at all. We could distinguish five different forms with certainty; three were bacilli and two micrococci. Some of the bacteria were motile. Here also the first plates made were quickly liquefied. The liquefying microbe was isolated from the more diluted plates, and proved to be a streptococcus, and not the bacillus isolated during meat diet. There was, secondly, a slender bacillus most constantly found on the plates. It was not observed on the plates made whilst the patient was upon meat diet. Yeast fungi were numerous.

We isolated in pure cultures from the agar and gelatine plates the following micro-organisms :—

1. A bacterium, resembling closely the bacillus coli commune, and probably identical with the bacillus already isolated during meat diet.
2. A non-liquefying diplococcus.
3. A non-liquefying diplococcus, smaller than the former.

Three forms were isolated from the anaerobic plates, viz., two species of cocci, morphologically identical with those already isolated aerobically. The third form was a bacillus, not found on the aerobic plates. It was a long and rod-shaped bacillus, and the bacilli were arranged in circular chains. It was not found on the plates during meat diet. In pure culture it grew also aerobically. We isolated altogether the following forms, amongst which were no putrefactive bacteria :—

1. A liquefying streptococcus.
2. A slender rod-shaped bacillus.
3. A large diplococcus.
4. A small diplococcus.
5. Bacterium, resembling bac. coli commune.
6. A "chain" bacillus.
7. Yeast forms.

Mould fungi were in this case not found.

We noted that with a change of diet, and after a lapse of time, quite different bacteria predominated—in this case, for example, the streptococcus liquefaciens and the slender rod bacillus. Of those isolated during meat diet we found only the bacterium, resembling the bac. coli commune. All the bacteria isolated were facultative anaerobic ; they grew aerobically and anaerobically.

III. *Cultures after a Meat Diet.*

Four weeks later, when the patient was again upon meat diet, inoculations were made for a third time from the intestinal contents, and the usual series of cultures therefrom.

As formerly, there were numerous bacteria present in the food-mass, and it was possible to distinguish six forms. There were also bacteria, which coloured badly or not at all, and motile bacilli. On the plates there was no general liquefaction of the gelatine, so that we were led to suppose that the liquefying forms already isolated were only sparingly represented in the intestinal contents at this time. Two forms were constantly found—a non-liquefying bacillus, with rounded ends, and an oval bacterium. Complementary experiments were now made

with sugar and glycerine gelatine. In all, seven forms were isolated:—

1. A rod bacillus, with rounded ends.
2. An oval bacterium.
3. A short rod bacillus, with flattened ends.
4. A micrococcus, which liquefies gelatine slowly and partially.
5. A short and thick bacillus, with rounded ends.
6. Yeast fungi.
7. A mould fungus.

The first two forms were present on all the plates, and especially numerous on the plates made with sugar and glycerine gelatine. On the anaerobic plates there were colonies of a bacterium, about the same size as the Bact. coli commune. It, however, slowly liquefied the gelatine. Here, again, all the micro-organisms were facultative anaerobic. On the whole the picture was different to that presented in the first and second series of experiments. The bacterial forms present in the small intestine seem to be in a perpetual state of change. After a lapse of time, and after change of diet, different forms prevail, and the previously predominating forms are pushed into the background or completely disappear.

These preliminary experiments being finished, our next object was to study more closely the morphology and physiology of those bacteria which were most constantly present in the intestinal contents, and which consequently might be regarded as typical forms. We hoped in this way to be able to arrive at a definite and just conclusion as to the share the bacteria take in the digestion and decomposition of the food in the small intestine.

The bacteria selected for the above reasons were:—

1. The bacterium resembling, and perhaps identical with, the bact. coli commune. (Meat diet, I.)
2. The streptococcus liquefaciens ilei. (Carbohydrate diet.)
3. The bacterium ilei. (Meat diet, II. 2.)
4. The bacillus liquefaciens ilei. (Meat diet, I.)
5. The oval bacterium or bacterium ovale ilei. (Meat diet, I. 3.)
6. The slender rod bacillus, or *bacillus gracilis ilei.* (Carbohydrate diet.)
7. The short rod bacillus, probably identical with the bacterium lactis aerogenes of Escherich. (Meat diet, II. 5.)

I. *The Bacterium resembling the Bacillus coli commune.*

It was given to Dr Bischler for chemical investigation, and accordingly we named it the "Bacterium Bischleri." It is a short rod-shaped bacillus. It varies greatly in size, on an average it is 4 μ long and 3 μ broad. The bacilli are usually in pairs, and are non-motile. Spores were not observed. In appearance

it resembles closely the bacillus coli communis, and at first we supposed it to be identical with the latter. It does not liquify gelatine. On gelatine the deep colonies have a yellowish colour, darker in the centre, and are finely granulated. The superficial colonies have a dull white colour (*v.* Plate X. fig. 1). The stabcultures in gelatine grow slowly as small dull white granules along the line of inoculation. Superficially the growth is slender, and forms a thin layer covering about two-thirds of the surface of the gelatine. The margin is irregularly curved. In agar the growth is similar. The bacillus coagulates milk at 38° C. within 22 hours. At 15° C. the milk is coagulated after 5 to 6 days. Guinea-pigs, after subcutaneous inoculation, died in 2 to 3 days.

The action of the bacillus on proteids and carbohydrates was next investigated:—

200 grammes dextrose were dissolved in 3 litres of meat broth, and 75 grammes carbonate of lime added. The solution, after sterilisation, was inoculated on the 16th July from a pure culture of the bacillus, and placed in an incubator at 37° to 38° C. Active fermentation set in, and there was an active development of gas. On the 9th day the development of gas abated, and the solution was examined as follows:—First of all its purity was tested, it contained only the bacterium Bischleri. The sugar was next estimated. The fluid reduced very slightly a faintly alkaline solution of copper—and examined in the polariscope there was no rotation. There was therefore only a minimal amount of unchanged sugar present. The fluid was next decanted from the deposit and distilled till the distillate, tested with iodine and caustic soda, gave no further iodoform reaction. On saturating the distillate with calcined potash, an alcohol was obtained, which, after drying over caustic potash, distilled constantly at 77° C. It was therefore pure ethyl alcohol, and about 6 grammes were obtained. The remainder in the retort was treated with oxalic acid, the oxalic acid precipitate filtered off, and the filtrate once more distilled. The volatile products (fatty acids) were exactly neutralised with soda, and the solution condensed on the water-bath. The soda salt was recrystallised out of alcohol, and precipitated with nitrate of silver. 0·2224 grm. of the silver salt from the first crystallisation, left, after combustion, 0·1435 grm. silver = 64·52 per cent. silver. From the second crystallisation 0·2043 grm. of the silver salt yielded 0·1332 grm. silver = 64·7 per cent. The acetate of silver contains 64·6 per cent. silver. The volatile acid was thus acetic acid, of which about 7 grms. was obtained. The remainder in the retort was concentrated to a syrup, and extracted with ether. After distilling off the ether a yellowish syrup remained, which, boiled with zinc hydroxyde, gave ordinary lactic acid. The zinc salt contained 17·98 per cent. of crystallisation and 26·82 per cent. Zn. The theoretical formula requires 18·18 per cent. water, and 26·74 per cent. Zn.

It is interesting to note that Dr Bischler obtained from sugar cultures of the *bac. coli commune* the *same* fermentation products, viz., ethyl-alcohol, acetic and lactic acids. The lactic acid obtained was, however, the *optically active* paralactic acid, with 12·9 per cent. water of crystallisation.

The two bacteria therefore differ from one another, inasmuch as their fermentation products are not wholly identical. The chief point of difference is that in the one case the optically inactive, in the other case the optically active, lactic acid was produced. We proved recently that the so-called sarco- or paralactic acid is formed out of sugar by the micrococcus acidi paralactici.[1] Since then we have found five forms of bacteria which produce from dextrose the optically active paralactic acid. We will describe these forms on another occasion. We may, however, suggest here that the production of the inactive or active lactic acid may prove a useful diagnostic method for distinguishing between individual forms of bacteria. Thus by means of this chemical test we were able to prove that the bac. Bischleri and the bac. coli commune were not identical, though morphologically they resembled one another closely. The bac. Bischleri has no action upon proteids. Finely minced meat was mixed with four times its volume of water and sterilised. After inoculation the culture was made anaerobic by replacing the air with carbonic acid. The flask was kept at 38° C. After seven days no gas developed, and the fluid remained clear. The flask was then opened, resterilised, and inoculated from fresh cultures. It was simply plugged with cotton wool. After 10 days at 38° C. there was no decomposition, the contents of the flask remained clear and odourless. Microscopically the number of bacteria was very small.

II. *Streptococcus liquefaciens ilei and Acidi lactici.*

The micrococci are small and delicate, and the chains often consist of 20 and sometimes 40 members (*v.* Plate X. fig. 2). They were easily stained with the ordinary aniline dyes. In gelatine they formed small round yellowish colonies, surrounded by a narrow zone of liquified gelatine. The "stabcultures" in gelatine were characteristic. On the surface there formed a

[1] *Wiener Akad. Ber.*, 1889.

saucer-like liquefaction of the gelatine. The liquefaction proceeded gradually from above downwards, and after three weeks two-thirds of the gelatine was liquefied. In agar they form a dull greyish-white layer covering the entire surface. In bouillon they grow rapidly. After 24 hours at 38° C. the bouillon is quite cloudy, and after 2 days there is a deposit of bacteria at the bottom of the tube. There was no putrefactive smell. Sterile milk was coagulated after 22 hours at 38° C. Guinea-pigs, inoculated from broth cultures, died after 24 hours.

In order to study the decomposition of sugar and albumen by this and the following microbes, we prepared two kinds of nutrient fluids:—

1. Dextrose, 40 grm.; Kemmerich's peptone, 12 gr.; calcium carbonate, 16 gr.; sodic-chloride, 2 gr.; and water, 800 grm.
2. Finely minced meat, 200 grm; and water, 800 grm.

These solutions were sterilised in flasks plugged with cotton wool. On the 21st August they were inoculated with the respective bacteria, and placed in an incubator at 38° C. On the 12th September they were taken out and kept at 15° C. till October, when they were examined. The sugar solution inoculated with the streptococcus liquefaciens ilei was microscopically examined. It contained only the above micrococci. The further investigation was conducted as described by the bac. Bischleri. There were only traces of unchanged sugar. A small quantity of alcohol was obtained, not sufficient for an accurate estimation of its nature. The concentrated liquid solidified on cooling to a crystalline mass, consisting of the lactate of calcium. A portion of the calcium salt was converted into the zinc compound and analysed. 0·2305 grm. lost at 110° C. 0·0423 grm. in weight, and gave after combustion 0·0623 grm. ZnO., *i.e.*, 18·34 water and 26·57 per cent. ZnO. It was therefore the inactive lactic acid. With the exception of small quantities of bye-products, the sugar was completely transformed into the inactive lactic acid. This microbe appears to be especially adapted to the production of lactic acid in the intestine.

The meat cultures were in part decomposed. The fluid was cloudy, strongly alkaline, and had the odour of old cheese, without reminding one of indol or skatol. Microscopically bacilli were also present. The culture being thus contaminated we did not examine it further.

III. *Bacterium ilei.*

It is a short rod bacillus with rounded ends, 2 to 3 μ long and 1 μ broad. The bacilli are usually in pairs, at times also in groups. They are feebly motile, and form spores usually at the two poles. They are easily coloured with methylene blue and Ziehl's solution. In gelatine the colonies grow well on the

surface, and exceed 5 or 6 times in diameter the deep colonies. They have a greyish-white colour. They are finely granulated, and three zones can be distinguished,—an inner brownish, then a yellowish, and a marginal of a yellowish-white tinge. The margin is irregularly curved (*v.* Plate X. fig. 3). The stab-cultures in gelatine form fine yellowish-white discrete granules along the line of inoculation. Superficially they form a dull white moist and thick layer, with a wavy margin, covering almost the entire surface. In agar the surface growth is similar; the deep growth is yellowish-white, and indistinctly granular. They grow rapidly in bouillon, and at 38° C. coagulate milk within 20 hours.

The sugar cultures on examination were found to be pure, and the fluid odourless. It reduced a weakly alkaline solution of cupric sulphate. On testing with Wild's polaristrobometer, the fluid was lævo rotatary = 40′ in a 100 μ tube.

The distillate gave a marked iodoform reaction. By saturating with potash, and drying and rectifying, we obtained 6 grm. of an ethyl alcohol which boiled between 76° and 77° C. at 706 mm. barometric pressure. The amount of alcohol obtained was equivalent to 15 per cent. of the sugar used. The remainder in the retort was acidified with HCl and extracted with ether, and then with alcohol ether (1 vol. alcohol and 2 vols. ether). We obtained as chief product succinic acid, and in smaller amount the active paralactic acid. After distilling off the ether and adding a small quantity of water, succinic acid crystallised out, whilst the lactic acid remained in solution. The mother liquid was filtered off from the crystals, and the filtrate boiled with zinc hydroxyde. The filtrate contained the soluble zinc lactate, and succinate of zinc remained as an insoluble precipitate on the filter. 0·1893 grm. of the salt lost at 110° C. 0·0239 grm. in weight = 12·62 per cent. H_2O; and 0·1654 grm. on combustion gave 0·0556 grm. ZnO = 27·0 per cent. zinc. The succinic acid was also analysed. 0·2246 grm. of the substance recrystallised out of water gave 0·3368 grm. CO_2 and 0·1083 grm. H_2O, or 40·89 per cent. carbon and 5·35 per cent. hydrogen. The formula $C_4H_6O_4$ corresponds to 40·68 per cent. carbon and 5·08 per cent. hydrogen.

We thought it possible that the second and until now unknown active ethylidene lactic acid might be formed by this bacterium from sugar.

We have accordingly asked Dr Frey to repeat the experiments on a larger scale.

Cultivated anaerobically in sugar, the gases formed were found to be carbonic acid and hydrogen. On the third day the gas collected consisted of CO_2, 57 volumes per cent., and H, 40 volumes per cent.

Albumen was not affected by this microbe. The meat cultures remained clear, and the meat was undissolved.

IV. *Bacillus liquefaciens ilei.*

They are small and delicate bacilli; 2 to 2·3 μ long and 0·4 μ in diameter. They form no spores, grow quickly, and are motile. Examined in a glass cell they dart across the field of vision with great rapidity. They do not colour well with the usual pigments, best of all with methylene blue. At 15° C. they grow rapidly on gelatine plates. After two days the colonies are visible to the eye as small round points. They have a sharp clearly-defined margin, produced by a liquefaction of the gelatine surrounding the colony. Examined with a low power the colony has a brownish tint, and the periphery is not sharply defined. Surrounding it is a layer of liquefied gelatine (*v.* Plate X. fig. 4). In stabcultures a tube-like liquefaction of the gelatine takes place. The liquefied gelatine contains dull white flakes consisting of masses of bacteria. At the bottom of the tube there is a whitish deposit of bacteria. At the end of two weeks the gelatine is completely liquefied. In agar the bacteria form a greyish-white moist pellicle over the entire surface. They grow quickly in bouillon cultures, kept at 38° C. After 24 hours the bouillon is quite cloudy, and after 2 days a thin pellicle forms on the surface, which on shaking falls to the bottom of the tube. There is no distinctly putrefactive odour. Fresh sterile milk is not coagulated by this bacillus.

Dextrose is only decomposed to a small amount. The culture was pure, the fluid neutral and without smell. It contained 3·2 per cent. unchanged sugar. On distilling we obtained a small quantity of alcohol, too small to determine its nature. There were traces of a volatile fatty acid, probably acetic acid. From the ether extract a zinc salt was obtained, not enough, however, for a trustworthy analysis.

In the flask containing meat, about half of the meat was decomposed. The fluid had the smell of old cheese. The reaction was strongly alkaline, and on adding caustic soda much ammonia was developed. It contained, however, neither indol, skatol, or methylmercaptan. The bacillus had therefore an action on proteids, and is being further investigated at present in this laboratory.

V. *Bacterium ovale ilei.*

The bacteria are almost circular, and in appearance at times closely approaching micrococci. Numerous transition forms were seen up to distinctly bacillary forms. On gelatine plates

the colonies have a brownish tint, and are round or oval, with an irregular contour (*v.* Plate X. fig. 5). In "stabcultures" they grow on the surface of the gelatine as a flat greyish-white layer, like the head of a nail. Along the line of inoculation the growth is granular and dullish white; at the lower part large, isolated, and bead-like colonies are seen. They grow quickly in meat broth, and there is no putrefactive smell. They do not coagulate milk.

The culture in sugar was pure. The solution contained 1·3 per cent. unchanged sugar. On distilling we obtained 3·5 c.c. ethyl alcohol. There were traces of a volatile fatty acid, most probably acetic acid. The remainder, after adding oxalic acid, and distilling, was extracted with ether. From the ether extract we obtained 0·4 grm. of a zinc salt. It was the active paralactic acid—0·216 grm. lost at 110° C. 0·028 grm. in weight = 12·9 per cent. water, and left after combustion 0·063 grm. ZnO = 26·87 per cent. zinc.

The albumen was unaffected by this microbe.

VI. *Bacillus gracilis ilei.*

It is a slender rod bacillus, about five times as long as broad. The bacilli are generally in pairs and are motile (Plate X. fig. 6). No spores were observed. On gelatine plates they form yellowish-white round colonies with sharply-defined margins. In "stab-culture" the gelatine becomes covered with a thin delicate pellicle of a dull white colour. In the depth the growth is feeble. In bouillon they grow well at 38° C. Milk is coagulated after twenty hours.

The sugar culture was pure, and contained 2 per cent. unchanged sugar. The amount of alcohol was about 4 c.c., of which the greater part distilled over at 77° to 80° C. A small quantity distilled at a higher temperature, but the amount was not sufficient to determine its nature. Traces of a volatile fatty acid were found, from the qualitative tests most probably acetic acid. The ether extract yielded about 0·3 grm. of a zinc salt. It was paralactic acid—0·186 grm. lost at 110° C., 0·023 grms. in weight = 12·36 per cent., and left on combustion 0·054 grm. zinc oxide = 26·58 per cent. Zn.

The meat cultures remained unchanged.

VII. *The Bacterium probably identical with the Bacterium lactis aerogenes of Escherich.*

These bacteria have sharply-rounded ends, are single, or united in pairs or in groups. On gelatine plates they form superficially

white glistening colonies. The deeper colonies have a yellowish tinge, and are round (*v.* Plate X. fig. 7). In "stabcultures" the growth is bead-like. Superficially they form a porcelain-white flat growth. The growth in agar is similar. They grow well and rapidly in bouillon. They coagulate milk within 20 hours at 38° C., but first after four days at 15° C. Like the bacterium lactis aerogenes they are pathogenic for guinea-pigs—the animals died in 2 to 4 days.

The sugar culture was optically inactive, though it still reduced an alkaline solution of sulphate of copper. The sugar was therefore almost entirely decomposed. On distillation, a large quantity of alcohol was obtained—about 8 c.c. On rectifying, it distilled at 77° to 79° C., with the exception of a small remainder. Acetic acid was present in small amount. The silver salt contained 64·55 per cent. silver. The remainder contained much succinic acid. The crystals melted at 180° C. A zinc salt was also obtained, most probably of lactic acid. Its amount was not sufficient for analysis. Anaerobic cultures of the bacterium were made in sugar solutions. The air was replaced by CO_2. There was an active development of gas. According to an analysis made by Dr Frey, the gases were CO_2, 72·38 per cent., and Hydrogen, 27·61 per cent.

It will be necessary at this point to make some general observations regarding the bacteria found in other sections of the digestive canal. We will then state the conclusions our investigations have led us to with regard to the share the bacteria take in the decomposition of the food. No one now doubts that the entire digestive tract (mouth cavity, stomach, small and large intestine) constantly contains bacteria.

The investigations of Sucksdorff[1] show that their number can vary greatly, according to the diet and its method of preparation, *i.e.*, the degree of sterilisation that takes place in cooking.

Miller[2] has made detailed researches as to the bacteria contained in the mouth cavity. He isolated a large number of micro-organisms which have their chief seat in the mouth. He further found that five of these produced a considerable development of gas in fluids containing sugar. We will mention two of these—the *Micrococcus aerogenes* and the *Bacterium aerogenes*—since it was possible that they might be identical with forms isolated by us.

Amongst the three bacilli isolated by Raczynski[3] from the dog's stomach after meat diet, one, the *bacillus geniculatus*, may possibly be identical with our *bacillus liquefaciens ilei.*

[1] *Archiv f. Hygiene*, vol. iv., 1886.
[2] *D. Med. W.*, 1884, Nos. 36 and 38; 1886, No. 8; 1888, No. 30.
[3] *Centralblatt für Bakter.*, vol. vi. p. 112.

Escherich[1] found very varying forms in the meconium, and amongst these bacteria usually found in putrefying fluids. The bacteria he isolated were—

1. Bacteria with swollen ends; not isolated in pure culture.
2. Rod bacilli; perhaps identical with bac. subtilis.
3. A small streptococcus which liquefies gelatine, called by him the s. coli gracilis.
4. Bacterium coli commune; few in number.
5. A number of micrococcus forms.
6. A yeast fungus.

In "milk fæces," on the contrary, there was not such a variety of forms. Two species were most constantly present—the bacterium coli commune, and the bac. lactis aerogenes.

Three of the above forms were also found in the intestinal tract, and the fæces of Carnivora, viz.:—

1. The bact. coli commune, especially numerous in the lower part of the digestive tract, and in the stools of sucklings. 2. The bacterium lactis aerogenes. 3. The streptococcus coli gracilis, chiefly in meconium fæces.

As regards the microbes in the large intestine of Man, we will mention the researches of Bienstock[2] and W. Booker.[3] The first author isolated from human fæces four microbes, one of which he regarded as the special cause of the decomposition of proteids. The second author investigated chiefly the fæces of sucklings. He found the bact. coli commune in the normal "milk fæces." In diarrhœic discharges the number of the bact. coli commune lessens proportionally with the severity of the attack. In its place appears as predominating form a short rod bacterium resembling the bacterium lactis aerogenes.

Amongst the forms more particularly studied by us are *three* which might possibly be identical with some of the forms isolated by earlier observers from the intestinal contents. These are—

1. *Streptococcus liquefaciens ilei*, with the *strept. coli gracilis.*
2. *Bacterium Bischleri*, with the *bac. coli commune.*
3. The *bacterium* or short rod bacillus vii., with the *bact. lactis aerogenes.*

The *Streptococcus liquef. ilei* differs in two points from the streptococcus coli gracilis of Escherich. It liquefies the entire gelatine from above downwards, and is pathogenic for Guinea-

[1] *Fortschritte der Med.*, vol. iii.
[2] *Zeitschrift für Klin. Med.*, vol. viii.
[3] *Centralb. für Bakter.*, vol. v.

pigs. Escherich's microbe produces a funnel-shaped liquefaction of the gelatine, and is non-pathogenic for Guinea-pigs.

Microscopically, the *bacterium Bischleri* resembles the bact. coli commune. The former, however, forms from sugar the *inactive*, the latter the *active* lactic acid. They are therefore not identical. For the same reason it is possible that the bacillus isolated by Gessner[1] from the human duodenum, and called by him bac. coli commune, may be identical with the bac. Bischleri.

As to the third microbe, it is most probably identical with the bact. lactis aerogenes. They are short and rod-like bacteria, about 2 μ long, and are slightly less in diameter. The size, however, is not constant; they are sometimes larger, at times more spherical in shape, and resembling cocci. They are facultative anærobic; coagulate milk within 24 hours at blood temperature, and in stabculture resemble closely the bac. lactis aerogenes. As already mentioned, they do not decompose albumen, but form out of sugar alcohol, succinic acid, acetic and lactic acids.

We did not find the Bienstock bacilli in the small intestine. It was therefore of interest to investigate the bacteria in the large intestine of the patient, who had not defæcated for two months. For this purpose the large intestine was washed out from the rectum with sterile salt solution. After a few minutes portions of the fluid flowing out of the *upper* end of the large intestine were collected for examination. Microscopically we could distinguish three species—

1. Streptococci, present in greatest number.
2. Short rod-bacilli, also numerous.
3. Slender bacilli, probably identical with Bienstock's bacillus. The number present was small.

The bouillon cultures soon acquired a putrid smell, and had a green fluorescent colour, both due to the streptococci. They also liquefied gelatine, which acquired a green fluorescent colour.

The short rod-bacillus in pure culture did not liquefy gelatine, and corresponded morphologically to the bac. coli commune.

On the plates also were bacilli, which produced in bouillon a putrid smell, but without fluorescence.

[1] *Centralb. für Bakter.*, vol. vi.

Two weeks later the experiments were repeated after the patient had received per rectum egg clysters. Microscopically, the appearance was much the same as in the former case, only the streptococci were relatively few in number. All samples from the large intestine developed in bouillon a disagreeable putrid odour, and the majority of the plate colonies consisted of a fluorescent putrefactive bacillus.

Our chemical and bacteriological investigations show that, under NORMAL conditions, the bacteria in the small intestine of Man do not, as a rule, decompose proteids, or do so to a very small degree.

The bacteria present in the normal small intestine decompose especially the carbohydrates, and the products of the decomposition are ethyl alcohol, the two lactic acids, acetic acid, and succinic acid.

These products were also isolated by us *directly* from the contents of the small intestine.

The proteids are decomposed in Man, in the *large* intestine, under formation of the well-known products, indol, &c.

Already Ewald, after his investigations on a patient with intestinal fistula, concluded that it was inadmissible to assume any other source for the indican and phenol than the *lower* part of the digestive canal. The same also applies to sulphuretted hydrogen and methylmercaptan.

In support of this statement we may mention the following fact. More than ten years ago experiments were made in the Berne Hospital with a view of testing the antiseptic value of the nitrate of bismuth. In the patients who died, and who had received bismuth, it was interesting to notice that the entire mucous membrane of the large intestine, from the ileo-cæcal valve downwards, had a dark velvet-like appearance, whilst the mucous membrane of the whole *small* intestine was merely reddened. Investigation showed that the blackening of the mucosa was due to sulphide of bismuth. The absence of the same in the ileum mucosa showed that there *no* H_2S was developed.

The general surveys made of the bacterial forms present in the small intestine, under normal and healthy conditions, show that these vary, even with a slight change in diet, or the way in which it is prepared.

There seem to be no bacterial forms that are specially bound to and constantly to be found in the small intestine, as, *e.g.*, seems to be the case with Leptothrix in the mouth cavity, and the bac. coli commune in the large intestine. One *characteristic* mark, however, for the bacteria of the small intestine is this—that by preference, so to say, they decompose carbohydrates and not proteids.

We cannot say with exactness how much of the sugar derivatives in the small intestine is due to the action of bacteria. This will depend on the following factor, viz., if those microbes which energetically split up sugar prevail amongst the others or not—*e.g.*, the streptococcus liquefaciens ilei, or the bacterium lactis aerogenes.

The organic acids formed out of the sugar are the causes of an increase in acidity of the chyme passing out of the stomach to such a degree that neither the alkali of the bile, nor that of the pancreatic juice, or of the entire mucosa of the small intestine, is sufficient to completely neutralise the food-mass.

An approximate notion of the amount of alkali furnished by the intestinal mucosa for the purpose of neutralising the acids, is furnished by the *ash*-analyses we made. These analyses were made not only after a proteid diet, but also after a diet in which carbohydrates predominated. The results are given in the table on p. 418. The intestinal contents, dried on the water-bath and then at 110° C., can be easily powdered. By heating on platinum an ash is left with a strongly alkaline reaction; on adding HCl, carbonic acid is given off.

The estimation of iron, silicic acid, alkaline earths and alkalies, was made as follows:—12·8828 grms. of the dry remainder after meat diet was carefully carbonised in a platinum dish, and heated till all organic matter disappeared. The soluble constituents of the ash were extracted with water, and filtered. The filtrate was evaporated in a platinum dish, and the remainder gently heated. Nitrate of ammonia was added to the remainder on the filter, which was then heated till a white ash resulted. This, after weighing, was added to the "soluble ash," and dissolved in HCl. The total amount of ash obtained was 8·33 per cent., of which 2·07 per cent. was soluble in water, and 6·26 per cent. insoluble. The usual analytical methods were employed for estimating the iron, silicic acid, and the bases.

The solution of the chlorine alkalies was repeatedly evaporated till no traces of baryta remained.

The chlorine, sulphuric and phosphoric acids, were estimated as follows:—30·9412 grms. of the dry remainder (equivalent to 2·5774 grms. ash) were dissolved in a 1 per cent. solution of nitric acid. The fluid was then filtered, the remainder on the filter washed till no further chlorine reaction was given by the filtrate. The filtrate + "wash-water" was then diluted to 800 c.c.: of this, 200 c.c. was

used each time for the estimation of the three acids. By estimating the acids by a moist method we avoided (1) any loss of chlorine, (2) any excess of sulphuric acid from the sulphur of the albumen, and (3) any excess of phosphoric acid from the phosphorus of the lecithin. The ash analyses of the intestinal contents, after a carbohydrate diet, were made in similar fashion. The following table gives the percentage amount of the different ash constituents:—

	After Proteid Diet.	*After Carbohydrate Diet.*
	[Ash in solid remainder =8·33 per cent.]	[Ash in solid remainder =8·6 per cent.]
	In 100 Parts Ash was found—	
CaO, . . .	29·58 per cent.	21·71 per cent.
MgO, . .	4·65 ,,	6·09 ,,
Na_2O, . .	31·53 ,,	30·94 ,,
K_2O, . . .	3·83 ,,	6·45 ,,
Fe_2O_3, . .	0·31 ,,	0·44 ,,
SiO_2, . . .	0·73 ,,	0·87 ,,
Cl, . . .	7·75 ,,	4·84 ,,
SO_3, . . .	1·22 ,,	0·47 ,,
P_2O_5, . .	14·46 ,,	10·68 ,,
Total, . .	94·06 ,,	82·49 ,,

The figures obtained are in several respects interesting. In both analyses the amount of the acids is much smaller than that of the bases. If we assume that in the first ash analysis all the chlorine is present as NaCl, the sulphuric acid as SO_4Na_2, and the phosphoric acid as PO_4HCa, then, in order to neutralise the mineral acids, 7·7 grms. Na_2O and 11·40 grms. CaO would be necessary. The remainder of the bases is united with organic acids, viz., 18·18 per cent. CaO, 4·65 per cent. MgO, 23·83 per cent. Na_2O, and 3·83 per cent. K_2O. From this it follows that 39·54 per cent. of the bases is combined with mineral acids, the remainder with organic acids.

If we make a similar calculation with regard to the mineral acids found after carbohydrate diet, the amount of alkalies necessary to neutralise them would be 4·54 grms. Na_2O, and 8·42 grms. CaO. The remainder of the bases united with CO_2 and organic acids would be 13·29 per cent. CaO, 6·09 per cent. MgO, 26·4 per cent. Na_2O, and 6·4 per cent. K_2O. From this it follows that 19·9 per cent. of the bases is combined with mineral acids, and the larger remainder with organic acids. In contrast to the salts formed with organic acids, the amount of the sodic chloride and of all the mineral salts is much less.

A very important and hitherto unregarded function of the intestinal mucosa is the supplying of alkali to the chyme. An

adequate neutralisation of the acid intestinal contents is of essential importance for the normal digestion in the small intestine. Should the mucous membrane furnish too little alkali, a hyperacidity of the intestinal contents must consequently ensue, whereby the separated mucin, instead of becoming mixed with the food-mass, is immediately precipitated on the intestinal mucous membrane. In the same manner also the bile acids would be precipitated. Digestion and absorption must thereby suffer. We have, as a matter of fact, observed that the more diarrhœic, semi-fluid intestinal contents contain the largest amount of sugar and acid—*vice versa*, an alkaline reaction of the intestinal contents would favour putrefactive changes.

Inasmuch as the mucosa furnishes the alkali as a carbonate, a portion of the CO_2 gas in the small intestine results from the neutralisation of the acid chyme. The remainder of the CO_2, as well as the hydrogen, result from the fermentation of the sugar.

It is the acids of the stomach and the small intestine which not only prevent the fermentative decomposition of albumens, but also limit the decomposition of carbohydrates. The earlier researches made prove this,[1] and also the more recent, especially made by us in this case. To bouillon we added lactic and acetic acid respectively, so that titrimetrically the fluid contained 1 per 1000 of each acid. It was then inoculated with the several bacteria isolated by us from the intestine. At 38° C. the fluid remained perfectly clear, and the growth of the microbes was completely suspended. After two days gelatine plate cultures were made, and on all colonies of the several bacteria grew. Thus the two acids in the above concentration did not kill the bacteria; they merely hindered their growth.

In apparent contradiction to this is the fact that numerous bacteria are to be found, not only in the intestine, where the acidity, as acetic acid, averages 1 per 1000, but also in the stomach, where the free HCl acid acts as an antiseptic. Experiments made on dogs with a strongly acid gastric juice proved that widely different bacteria (*e.g.*, micrococcus tetra-

[1] N. Sieber, *J. für Prakt. Chemie*, vol. xix.; and Thol, *Ueber den Einfluss Organ. Säuren auf Fäulniss u. Gährung*, Griefswald, 1885.

genus, st. aureus, and bacillus of rabbit septicæmia) passed through the stomach unscathed, and could be isolated again from the small intestine.[1] The reason for this is probably that the bacteria differ from one another in their susceptibility to the action of acids. In general those which decompose carbohydrates are more resistant than those which decompose proteids. Of those taken up with the food a number will certainly be destroyed in the stomach. The inimical action of the acid is also exerted in the whole length of the small intestine, so that during our investigations we never were able to isolate *putrefactive bacteria* from the intestinal contents. On the other hand, putrefactive bacteria were easily and constantly isolated by us from the large intestine of the same patient.

Probably only isolated spores of the bacteria which decompose proteids pass into the large intestine, where they settle down and develop.

It may be that *exceptionally* the contents of the large intestine have an acid reaction. Each time we examined the fæces of healthy and sick people the reaction was alkaline.

A second reason why isolated bacteria escape the inimical action of the acids is more of a mechanical nature. It can easily be demonstrated in animals, especially in the larger herbivora, *e.g.*, horses. If a horse, after being fed, is bled to death, and the stomach opened, the mucous membrane is found to have a strong acid reaction. The food lying on the mucous membrane is also acid, but at spots removed from the walls of the stomach, *e.g.*, towards the middle, the reaction is either neutral or alkaline. Notwithstanding the peristaltic action, all portions of the food-mass do not come into such intimate contact with the mucous membrane as to allow the acid of the same to kill the bacteria present in the separate particles of the food. It has further been shown by one of us that the bile and the bile acids have no marked antiseptic action.[2] The bacteria isolated by us grew well in gelatine containing 2 per cent. of bile.

On the 13th of November, *i.e.*, exactly six months after establishing the fistula, Professor Kocher once more united the small and large intestine. The patient made a good recovery; on the ninth day after the operation the first stool passed per rectum. The patient's condi-

[1] Macfadyen, *Jour. of Anat. and Phys.*, vol. xxi.
[2] Macfadyen, *Jour. of Anat. and Phys.*, vol. xxi.

tion continued to improve, and on the 19th December she was discharged as cured. During six months her large intestine was inactive. During this period it was completely shut off from the digestive process, excepting when a few peptone and egg clysters were administered, with a view of testing the absorption taking place from the large intestine.

It was of interest to ascertain how much of the food becomes digested and absorbed in the stomach and small intestine, and what share the large intestine takes in the process.

The patient received daily:—

In	260	grammes	Bread	16·2	grms.	albumen	=	2·6	grms. N. [1]
,,	100	,,	Meat	20·8	,,	,,	=	3·33	,, N. [2]
,,	200	,,	Barley gruel	8·21	,,	,,	=	0·514	,, N. [3]
,,	2	eggs	. . . . .	12·55	,,	,,	=	2·0	,, N. [4]
,,	20	grammes	Peptone	9·57	,,	,,	=	1·53	,, N. [5]
,,	100	,,	Milk	3·41	,,	,,	=	0·547	,, N. [6]
,,	1050	,,	Bouillon	5·0	,,	,,	=	0·081	,, N. [7]
			Total . .	70·74	,,	,,	=	10·602	,, N.

With the above diet, the amount of nitrogen in the dry remainder of the intestinal contents was 5·39 per cent. and 6·78 per cent., or on an average 6·08 per cent. The maximum amount of the semifluid discharge from the fistula was 550 grammes, with 4·9 per cent. of solid matter. The maximum amount of the consistent and porridge-like discharge was 232 grammes with 11·23 grms. of solids. The average amount of solids in 24 hours was 26·5 grms., containing 1·61 grm. N. = 10·06 grms. albumen. Inasmuch as the patient received in her daily diet 70·74 grms. albumen, it will be seen that only the seventh part of the albumen contained in her food (*i.e.*, exactly 14·25 per cent.) remained over for digestion and absorption in the large intestine, whilst 85·75 per cent. was absorbed in the stomach and small intestine. Carbohydrates were not absorbed to the same extent. They are decomposed largely in the large intestine, and also considerably by the bacteria of the digestive tract. Given in quantity they were discharged unchanged, as was proved by our experiments with mashed peas. Similar results were obtained by Bischoff and Voit in their experiments with dogs (*Die Gesetze der Ernährung des Fleischfressers*, Leipzig und Heidelberg, 1860, p. 290). A healthy dog, after a purely meat diet, discharged 27–40 grms. fæces in 24 hours in which were contained about 12·9 grms. solid remainder,

[1] König, *Die menschlichen Nahrungsmittel.*

[2] Estimated by us in the meat.

[3] Here also we estimated the amount of N., and calculated as albumen by multiplying with the co-efficient 6·25.

[4] One egg weighs 50 grammes. Albumen and N. were estimated according to König, p. 178, *l.c.*

[5] According to Pouchet's analyses of Kemmerich's peptone.

[6] König, *l.c.*, p. 203.

[7] The bouillon contained 2·2 per cent. solid remainder, and 0·162 per cent. N. Probably only half of the N. found therein is contained in the albumen and peptone; the "meat bases" contain the rest. Therefore 0·081 grm. N. = 5·0 grm. albumen.

although the amount of meat given varied from 500 to 2500 grammes. The fæces were blackish, of the consistence of pitch, or solid, and were only discharged at intervals of several days. On the other hand, the fæces, after a diet of bread, were discharged at least once daily, and the amount was larger. The amount of solids corresponded to one-sixth or one-eighth of the bread consumed.

Bischoff and Voit found in their first experiments, that after giving the dog 857 grammes bread daily (containing 460 grms. solids), 377 grammes fæces were discharged, in which were 76 grammes of solids. This corresponds to 16·6 grammes fæces for every 100 grms. of bread. The fæces after a bread diet are yellowish-brown, friable, strongly acid, and are coloured deep blue by iodine.

If the percentage composition of the fæces after a bread diet be compared with that of bread, it will be found that the fæces consist almost entirely of unchanged bread, which the digestive apparatus is not able to assimilate. The percentage composition of the fæces after a meat diet on the other hand differ greatly. This will be made clear by the following table:—

	Bread.	Bread Fæces.	Meat.	Meat Fæces.
C.	45·51 per cent.	47·39 per cent.	51·95 per cent.	43·44 per cent.
H.	6·45 ,,	6·59 ,,	7·18 ,,	6·47 ,,
N.	2·39 ,,	2·92 ,,	14·11 ,,	6·50 ,,
O.	41·63 ,,	36·08 ,,	21·37 ,,	13·58 ,,
Salts.	4·12 ,,	7·02 ,,	5·39 ,,	30·01 ,,

By administering clysters to our patient per rectum we attempted to determine how much of the nutriment is retained and absorbed in the large intestine. We used for the injection Kemmerich's peptone and the contents of eggs beaten up in physiological salt solution. It was important to regulate the amount of fluid injected. When a large quantity was used a considerable portion was lost through the ileo-cæcal fistula. 100 grms. peptone were dissolved in 100 c.c. water, and injected into the rectum in two portions on the 28th of June. A portion was discharged from the fistula. Six hours after the injection 30 grms. of fæces were discharged, having a distinct odour and containing numerous triple phosphate crystals. The injections were repeated, the patient receiving this time only 80 grms. peptone dissolved in 80 c.c. of physiological salt solution. It was injected in two portions, an interval of four hours elapsing between the injections. In this case the *whole* of the peptone was retained, and during several days there was no discharge from the rectum. Five eggs were next mixed with 0·6 per cent. salt solution, and the whole diluted to 250 grms. This mixture was injected into the rectum in three portions on the 19th of July. Here also there was no discharge of the injected fluid from the fistula, nor from the anus. Thus 30 to 40 grms. of albumen were retained, and absorbed in the large intestine.

It is some years since Pasteur[1] raised the question as to the indispensability of bacteria in the digestive process. Our researches seem to negative the view that they take an active and necessary share in the decomposition of the food in the intestine of man. Pasteur communicated to the Paris Academy researches made by E. Duclaux with seeds sown in a sterilised soil. The soil contained neither nitrates nor nitrites and no ammonia, but was soaked with sterile milk, cane sugar, or starch-paste. The seeds received thus, instead of the usual simple carbon and nitrogen compounds, complex organic bodies as above. After one to two months the milk was still unchanged. It remained uncoagulated, and the casein was still precipitable by acids. The seeds behaved exactly as in the experiments of Boussingault with distilled water. Their dry weight became less and less the longer they remained in such a soil. The results with sugar and starch were similar. Duclaux concluded, and rightly, that plant life and growth are only possible when micro-organisms are present in the soil. The microbes break up the complex constituents of the mould into the simpler compounds, such as CO_2, H_2O, NH_3; nitric and nitrous acids, which can be utilised by the growing plant.

Pasteur added the following observations:—

"It would be highly interesting to feed a young animal from its birth on pure food constituents, *i.e.*, a nutriment artificially and entirely freed from all microbes. Without wishing to make a positive statement, I will not conceal the fact that if I had time to undertake the experiments I would do so with the preconceived opinion that life under such conditions would be impossible. Should such experiments prove to be capable of simplification, one would then, perhaps, be able to investigate the influence on digestion of the systematic addition of one or other of the different microbes to the food. The hen's egg would present the least difficulty, and be most suitable for such experiments. Before the chicken was hatched it would be necessary to clean the egg very carefully, and to place the hatched chicken at once in a space free from all bacteria, into which one could introduce pure air and pure food (water, milk, grain). Whether the results were positive or negative, the carrying out of the experiments would be of the greatest interest."

The opinion has already been expressed by one of us[2] that no one would probably question the proposition, "No plant-life in

[1] *Comptes rendus*, F. 100, p. 66.

[2] *Archiv für Exper. Pathol. u. Pharmak.*, vol. xx., 1885.

Nature *without* bacterial life." But, on the other hand, Pasteur's preconceived opinion, as stated above, is most likely an erroneous one, at least as regards vertebrate animals.

We have seen that, when the acid chyme passes from the stomach into the intestine, it becomes neither neutral nor alkaline, but preserves its acid reaction down to the ileocæcal valve. As a result of the acid reaction, a decomposition of proteids by bacteria does not take place, or at most inconstantly and to a hardly perceptible degree. And not only that, the action of the pancreatic juice on proteids is weakened by the acid reaction of the intestinal contents. The products so easily obtained outside the body by the action of trypsin on proteids (leucin and tyrosin) were *not* to be found in the small intestine. Further, the decomposition of the food-mass by bacteria is confined to the carbohydrates. The products formed by the bacteria from sugar are—the two lactic acids, acetic acid, succinic acid, ethyl alcohol, carbonic acid, and hydrogen. The ash analyses we made prove that an important function of the small mucosa of the intestine is to supply constantly alkaline carbonates for the purpose of neutralising the acids produced by the fermentation of the sugar. No one can suppose that these fermentation products are necessary for the maintenance of our life. It is much more to be regarded as a loss that a portion of the dextrose formed by the pancreatic enzyme out of starch is not absorbed, but serves as nutriment for the parasitic bacteria of the digestive tract.

It will be unwelcome news for some that a considerable amount of alcohol is produced in our bodies, not only in the small, but also in the large intestine, in the latter by the bacterium coli commune. The possible decomposition of the fats by the bacteria does not need to be considered here. It has already been shown by one of us[1] that the presence of bacteria does not materially affect the disintegration of fat in the intestine. The excellent researches of Immanuel Munk[2] have proved that about 90 per cent. of the food fats are absorbed as neutral fats, and that free fatty acids are already transformed into neutral fats in the walls of the intestine.

[1] *Archiv f. Exper. Pathol. u. Pharm.*, vol. xx. p. 374.

[2] *Virchow's Archiv*, vol. xxv. pp. 407–467.

With Munk's research before us, we felt it was hardly necessary to undertake an exhaustive inquiry into the composition of the fats in the small intestine of our patient.

During six months our patient lived with her large intestine completely cut off from the digestive process. During that time she gained in weight, and, as will be seen from the table giving the daily amount of urea excreted, the exchange of nitrogen increased constantly.

The emaciated body of the patient first of all retained a certain amount of the proteids, and it was only gradually that the nitrogen excreted in the urine came to correspond to the amount of nitrogen absorbed with the food.

Any considerable decomposition of the food by bacteria *first* takes place in the large intestine, and in our patient it was shut off from the rest of the digestive tract. It follows that the digestive juices alone, *without* the co-operation of bacteria, are able to prepare the constituents of our food for absorption, and to furnish the necessary material for the conservation of life.

The fermentation products of proteids in the large intestine are chiefly indol, skatol, phenol, lactic acid, volatile fatty acids, aromatic acids, organic bases and ammonia; the gases are carbonic acid, hydrogen, methan, sulphuretted hydrogen, and methylmercaptan. It is easy to see that none of these products are foodstuffs.

The organism has no need of these products; on the contrary they are injurious and burdensome to it when produced in excess in the intestine.

The facts that we consider to have proved with regard to man, may well also apply to other vertebrates. But here also the conditions may, in certain cases, be more complicated, *e.g.*, in herbivorous animals, and especially the ruminants where already in the first stomach a fermentation of the food takes place, and seems in this case to argue in favour of the necessary co-operation of bacteria.

[TABLE

Table showing the amount of Urea excreted by the patient, M. Spycher, from 15th June to 2nd August 1890,

(The Urea was estimated by Hüfner's method.)

Date.	Urine in 24 hours.	Reaction.	Specific Gravity.	Urea in per cent.	Urea in 24 hours.
	cc.			Per cent.	Grammes.
15th June . .	1260	Acid	1012	0·67	8·51
16th ,, . .	1100	,,	1011	0·736	8·09
17th ,, . .	a portion lost	,,	1010	0·916	...
19th ,, . .	1510	,,	1010	0·906	13·68
20th ,, . .	830	,,	1017	1·564	12·981
21st ,, . .	1010	,,	1010	0·85	8·58
22nd ,, . .	1220	,,	1013	1·081	13·18
23rd ,, . .	1240	,,	1012	1·002	12·42
24th ,, . .	1730	,,	1010	0·73	12·62
25th ,, . .	1150	,,	1015	1·19	12·07
26th ,, . .	1020	,,	1020	1·56	15·9
27th ,, . .	780	,,	1017	1·644	12·82
28th ,, . .	1375	,,	1015	1·394	19·23
29th ,, . .	1058	,,	1012	0·9234	9·76
30th ,, . .	1060	,,	1013	0·9234	9·78
1st July . .	782	,,	1021	1·64	14·62
2nd ,, . .	1225	,,	1015	1·199	14·68
3rd ,, . .	1450	,,	1015	1·21	17·59
4th ,, . .	1390	,,	1012	1·259	16·87
5th ,, . .	1000	,,	1013	1·035	10·35
6th ,, . .	1800	,,	1010	0·772	13·89
7th ,, . .	710	,,	1020	1·56	11·07
8th ,, . .	1485	,,	1013	1·12	16·63
9th ,, . .	1485	,,	1013	1·07	15·88
10th ,, . .	920	,,	1019	1·88	17·29
11th ,, . .	1200	,,	1014	1·22	14·73
12th ,, . .	1260	,,	1014	0·871	10·97
13th ,, . .	1080	,,	1012	1·028	17·27
14th ,, . .	1156	,,	1014	1·24	14·33
15th ,, . .	1005	,,	1017	1·624	16·32
16th ,, . .	955	,,	1017	1·87	16·87
17th ,, . .	1170	,,	1015	1·42	16·66
18th ,, . .	700	,,	1025	1·59	11·13
19th ,, . .	1005	,,	1020	1·59	15·97
20th ,, . .	1500	,,	1015	0·877	13·15
21st ,, . .	1080	,,	1013	1·038	11·24
22nd ,, . .	1460	,,	1014	1·19	17·40
23rd ,, . .	1225	,,	1018	1·57	19·23
24th ,, . .	2004	,,	1010	0·913	18·84
25th ,, . .	2030	,,	1010	0·786	15·95
26th ,, . .	1260	,,	1012	1·16	14·61
27th ,, . .	1630	,,	1013	1·09	17·76
28th ,, . .	985	,,	1013	1·33	13·10
29th ,, . .	1690	,,	1011	1·20	20·28
30th ,, . .	1020	,,	1014	1·36	13·91
31st ,, . .	1230	,,	1014	1·23	15·12
1st August .	1540	,,	1013	1·37	21·09
2nd ,, . .	890	,,	1020	2·088	18·58

EXPLANATION OF PLATE X.

Fig. 1. Intestinal contents after meat diet.

Fig. 2. Intestinal contents after carbohydrate diet. The starch grains treated with iodine.

Fig. 3. *a*, *Bacterium Bischleri*, deep colony in gelatine; *b*, *Bacillus Bischleri*.

Fig. 4. *Streptococcus liquefaciens ilei.*

Fig. 5. *a*, *Bacterium ilei*; *b*, the same as a colony in gelatine.

Fig. 6. *a*, *Bacillus liquefaciens ilei*; *b*, the same as a colony in gelatine.

Fig. 7. *a*, *Bacterium ovale ilei*; *b*, the same colonies in gelatine.

Fig. 8. *Bacillus gracilis ilei.*

Fig. 9. *a*, Bacterium, probably identical with *bacterium lactis aerogenes*; *b*, the same, a gelatine colony.

SOME POINTS IN THE ANATOMY OF THE SUB-OCCIPITAL REGION. By ALBERT S. GRÜNBAUM, *Caius College, Cambridge.*

OF the points in the anatomy of the suboccipital region to which I wish to call attention, some have reference to the bony and others to the soft parts, and I propose to take them in that order; beginning with what has been aptly designated by Professor Macalister the "*paracondylar process.*"

FIG.—*fm*, foramen magnum; *oc*, occipital condyle; *acf* and *pcf*, anterior and posterior condyloid foramina; *pcp*, paracondyloid process; *m*, mastoid process; *pp*, paroccipital process; *pc*, parajugular canal; *arch*, bony arch.

Along the posterior third, or a little more, of the outer margin of each occipital condyle, there may be found, in a considerable percentage of skulls, a more or less prominent process varying very much in different races and different skulls.

In the skull which gave the first idea for examining this part more closely, the process on either side was continued in a peculiar manner such as to merit a special description.

The head was that of an Egyptian mummy dating from about 1500 B.C. On cleaning the skull, there appeared, on either

side, an arch bridging over the posterior condylar foramen. On the right side this arch was complete; it spanned a space of 9 mm.; its greatest vertical height was 8 mm.; its outer anterior portion 10 mm. from the foramen magnum. The inner posterior pillar touched the bone 4 mm. from the foramen magnum, 6 mm. from the most posterior point of the condyle. It arose from, and was continuous with, a bony eminence lying on the outer side of the condyle along its hinder third. This eminence—the paracondylar process—was 11 mm. long and 4 mm. broad; the bony archway arose from the hinder portion. Both process and arch were formed of very light spongy bone.

The left side was slightly different. The process measured 11 mm. by 6 mm., and was much more prominent than on the right side. The arch arose from the whole of the outer side of the process, but did not fuse with the occipital bone on its inner side; there was an interval of about 2 mm. The height of the arch on this side was 11 mm.

In a second special case (see fig.), also an Egyptian skull, there was a well-marked paracondylar process on the left side, but the arch did not arise from it. This arch bridged over the posterior condylar foramen anteriorly, and ran at right angles to the direction of that in the other skull described, viz., from within outwards, forming but a small angle with the axis of the condyles, and entirely posterior to the paracondylar process. In fact, it bridged the foramen nearly transversely, whilst the other ran almost antero-posteriorly. This arch was 10 mm. long and 5 mm. high to its lower border. More exactly, it arose just behind the condyle 4 mm. from the foramen magnum, and ended, after running outwards and slightly backwards, 11 mm. from the foramen magnum on the lip of a fair-sized depression on the outer side of the paracondylar process.

I examined several skulls—altogether 250—to see to what extent this paracondylar process might be present, and also the soft parts of a number of bodies to see whether the arch was represented, or to what extent it was represented, by ligamentous structures.

I found the process to be very variable as regards size, and also, to some extent, as regards position; but to be present in some form or other in a considerable percentage of skulls. For

convenience and system a classification was adopted which I shall immediately describe, but it may be as well to state first the general characters and limits of the varieties found.

The process may be very prominent up to the dimensions given above, and may be smooth or rough; it may be rounded, or narrow and long; limited to about the level of the middle of the condyle, or extending all along the posterior part—in this case being usually low and rough. It appears sometimes as a very small tuberosity; sometimes as a small spur. The process and the bit of arch proceeding from it are perfectly continuous. Lastly, there may or may not be a corresponding roughness or tubercle on the foramen to correspond to it, for insertion of the ligament proceeding from the process.

The mode of classification was as follows:—

Class I. Process and bony arch complete or nearly so. In this class were only the two Egyptian skulls, and perhaps three others, a Mulatto, a Papuan, and a Polynesian; but in these latter much smaller than in the Egyptians.

Class II. Process having a spur arising from it. There are but few of this kind—only six in the 250 examined. One Egyptian, two Polynesian, two Torres Straits, and one Old English. This last is a very remarkable specimen: the spur overhanging the posterior condylar foramen was exceedingly broad and massive. Unfortunately I had no callipers with me—the skull is in the Natural History department of the British Museum —and could measure only the breadth, which was nearly 9 mm.

Class III. Process as a rough eminence. In this class are twenty-eight of various races.

Class IV. Process as a smooth eminence. In this are twenty-nine of various races.

Altogether, out of 250 skulls examined, 88 showed the process, viz., rather over 35·2 per cent.

In close connection with this are two tubercles, usually very prominent where the paracondylar process exists, but sometimes present alone. These might be called the *internal* and *lateral posterior condylar tubercles* respectively. They are present—the former close to the foramen magnum behind the condyle,

and the other somewhat outside; and a ligamentous bridge often exists between the two.

In nine cases these were found, either together or singly, where the paracondylar process was absent.

The details about them are—3 with marked internal tubercle, 1 with marked internal spur, 2 with marked internal tuberosity, and 3 with internal and lateral tubercle.

As regards race, the numbers are scarcely large enough to make any definite statement; but I believe the process to be more frequent in Egyptian than other skulls—it certainly is more prominent—and comparatively infrequent in Australian and Polynesian skulls.

Another undescribed point (probably noticed, however, by many) is a bony tunnel or groove on the edge of the jugular foramen running along it for a variable distance, giving passage to a small vein which evidently goes to the anterior condylar foramen, and which might be called the *parajugular canal*. It is variable in diameter and length, and occasionally is double or even triple; in the latter case there is often a tunnel which passes round the outer edge of the occipital condyle.

It is formed by a bridging over of the occipital groove, made probably by an extended growth of the posterior lip of the jugular foramen overlapping the occipital groove, and fusing with the bone internal to it; but in very many cases it is confined to the edge of the jugular foramen only. All stages of completeness are found, but in every case the growth is from the lip of the jugular foramen; no corresponding outgrowth is ever seen on the inner side.

In 200 skulls examined, the tunnel was present in 75, or 37·5 per cent., whilst the groove, more or less deep, was found in 57, or 28·5 per cent.

A few measurements were made: the tunnel was generally 3–4 mm. long, and the groove in these cases unusually deep and 8–10 mm. long. In these cases, too, the tunnel existed on one side only, but the groove was then very deep on the other. This is very often found, and the tunnel does not appear to be more frequent on one side than the other. In a not inconsiderable number it was found on both sides.

Generally a paracondylar process varies with the size of the posterior condylar foramen; the jugular tunnel varies, if anything, inversely with the size of the vessel going through, being generally of greater diameter when incomplete than when complete.

With regard to the soft parts corresponding, or in connection with the bony structures just described, these consist chiefly of ligaments bridging over the part between two processes, or corresponding partly to portions ossified in the specimens described above.

From the paroccipital process inwards on the occipital bone, just by the posterior condylar foramen, there runs a ligament 3 cm. in length, and broadening out at the end, so as to bridge over the foramen, and at the same time to form a tunnel for a small branch of the occipital artery which curls round it on the outer side of the posterior condylar vein. On the inner side of the anterior end of this ligament is the attachment of the transverse atlanto-occipital ligament.

Running parallel to the first ligament, and arising from the hinder border of the transverse process of the atlas, is a stronger ligament inserted on the inner side of the posterior condylar foramen. A thin band of fibres joins these two, so that the whole forms a canal for this portion of the posterior condylar vein—there being, in addition, at the anterior third, the lateral atlanto-occipital ligament covering it below and on the outer side.

Beside these two, there are a number of oblique ligamentous bands running from the outer portion of the upper surface of the posterior arch of the atlas inwards to be inserted into the periosteum of the occipital bone about 5 mm. from the edge of the foramen magnum; these bands are two to four in number, and form distinct portions of the posterior atlanto-occipital ligament. The existence of these oblique bands is possibly due to their being more effective when placed thus than if they were vertical in preventing dislocation of the atlas forwards.

I have to thank Professor Flower, C.B., and Professor Stewart, for permission to examine the collections of skulls in the British Museum and Museum of the College of Surgeons respectively, and Professor Macalister for his very kind advice and assistance throughout.

REPORT ON RECENT TERATOLOGICAL LITERATURE. By BERTRAM C. A. WINDLE, M.A., M.D., *Professor of Anatomy in the Queen's College, Birmingham.*

Cleft Lobule of the Ear.

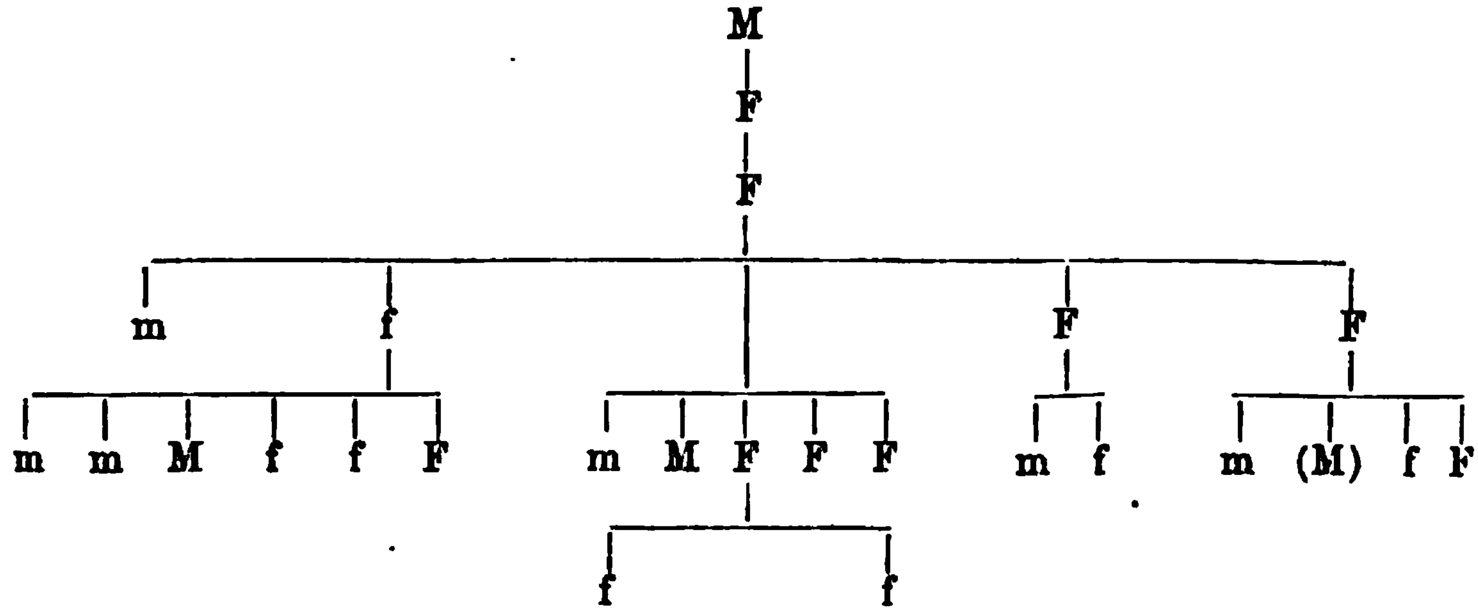
THIS subject, which has attracted much attention of late, was first brought into prominence by the paper of Schmidt (1) describing a case where a mother had acquired a cleft of the lobule of the left ear by the tearing through it of an earring whilst at play, at the age of eight years. She had eight children, of whom the second, a boy, presented a cleft of the lobule of his left ear, which the writer considered as an inheritance of the maternal mutilation. His (2) and Weissman (3), however, in reply, pointed out that the position occupied by the cleft in the son's ear was quite different to that of the mother's. So far the controversy on this subject is well known to English readers from the translation of Weismann's *Essays on Heredity.* Since the appearance of that book the following papers have appeared on the subject:—Israel (4) has described two cases of cleft lobule, in which there was no lesion of any kind in the ears of the parents. In the same paper he points out that the cleft always occupies a position corresponding to that called by His the sulcus intertragicus in the developing ear, and that, when present, it is, therefore, a remnant of this sulcus. Ornstein has described (5) three cases similar to those of Schmidt. In the first of these, a child of five years of age, the lobule of the right ear presented a fissure 4 to 5 mm. in height, which was congenital and unilateral. The mother had a similar deformity also in the left ear, but in her case it was due to an accident with an earring. She had two younger children with normal ears. The second case was that of a young man of twenty-seven years, whose right lobule presented on its outer surface a groove 3 mm. deep, terminating in a *cul-de-sac.* His elder brother (the third case) had on the outer surface of both his lobules a groove slightly curved, somewhat larger and deeper on the left side.—M. Laloy, after describing these cases in *L'Anthropologie,* goes on to say: "The author explains this strange formation of the lobule by heredity. The father of the young men wore earrings in his youth, and it is the slight deformity produced by the piercing which has become hereditary, though only in a portion of his descendants, since four other children present nothing abnormal. The fact becomes less unlikely if we remember that in the country where the observation was made (Asia Minor) it is a widespread custom for the men to wear earrings, and it is possible, therefore, that a predisposition accumulated through a long course of generations may have taken effect."—Dr v. Swiecicki (6) has, still more recently, recorded another case of the same kind. A female of scrofulous diathesis had her ears pierced three times for rings, and

on each occasion the operation was followed by prolonged suppuration. One of the lobules was also torn by a child pulling the ring. After this the woman bore a female child, well developed in all respects, but having on the right side a deep cleft in the lobule of the ear, which divided it into two unequal halves. On neither side of the cleft which ran in the direction of the anterior half of the tragus was any cartilage to be felt. The author regards this cleft as an arrest of development, causing a persistence of the sulcus intertragicus. In a note to the paper just mentioned, His says that v. Swiecicki discusses the question as to whether this fissure is the remains of the sulcus intertragicus, *i.e.*, of the original cleft between the inferior maxillary and hyoid arches. There is, however, another possibility, that the fissure exclusively belongs to the hyoid arch, and passes between the 5th and 6th tubercles of the rudimentary ear. Looked at from a developmental point of view, the complete ear has a natural limit where the lingula bends round to the antitragus, which limit is exceptionally well marked in some ears. In the ear of the mother, in the case in question, the region of the lingula appears as a strong connecting arch which, below the fossa navicularis, unites the tuberculum retrolobulare with the anterior border of the antitragus. The oblique furrow which passes along here in front of the arched piece corresponds unmistakably with the cleft of the child's ear. Similarly, the tubercle on the child's ear, which lies in front of the cleft of the margin and under the incisura intertragica, is to be regarded as the lobe of the ear, and the track of the embryonic branchial cleft is to be sought in front of this tubercle, which latter should not contain any cartilage. Interrogated on this point, v. Swiecicki replied that the tubercle in question was soft, and contained no cartilage. In the maternal ear the elevation from the anterior border of the antitragus to the helix is very strongly marked. It clearly separates the fossa navicularis from the cleft in the ear-lobe. There is also, at the margin of the ear to which the elevation reaches, a depression or cleft. Thus, continues His, the anatomical examination of the two ears shows that in the child a line of separation exists in a remarkable manner, which in the mother is, however, well marked. The division between cartilaginous and non-cartilaginous parts of the lower ear is, in the mother, a distinct groove, in the child an actual cleft. Therefore, it is not the accidentally produced, but the natural peculiarity of the mother's ear which the child inherits.

It is exceedingly interesting that the malformations of the lobule described in the above reviewed cases should have been unnoticed, apparently, until the examination of Weismann's views as to the transmissibility of acquired characters led observers to pay greater attention to minute deviations from the normal which appeared to throw some light on the controversy in question. It seems highly probable that, attention having been directed to this condition, it may, on further investigation, prove to be of much more common occurrence, at least as a minor degree of defect, than is at present suspected.

Whilst the subject of malformations of the ear is under discussion,

a case narrated by Laloy (7) may be mentioned, though differing in nature from those which have been already described. The subject of the deformity was a female aged twenty-seven, and the malformation was bilateral, though somewhat better marked on the right side than on the left. The ear was much smaller than normal, and, instead of lying nearly parallel with the side of the head, it projected like a shell, covering over the greater part of the auditory aperture, and almost touching the tragus. The postero-internal surface of the pinna, here become external, was alone visible. Almost the entire surface of the pinna was composed of firm cartilage, the free border, occupying its anterior third, being alone fleshy. There was no trace of antitragus, helix, or antihelix. In brief, the pinna was reduced to a concha, and one which had deviated from its normal position. The malformation did not in any way affect the sense of hearing, and the patient presented no other deformity. In endeavouring to explain the condition, the author gives an account of the development and appearance of the pinna at various periods of intra-uterine existence. At the conclusion of this account he says—"It is evident that this form of pinna neither belongs to the simian stage of the last months of intra-uterine life nor to the period of transverse folds characteristic of the fourth month. We must here call attention to the presence of a well-marked groove separating the upper two-thirds of the pinna from the lower third. There appears to be here a trace of the division of the pinna into three tubercles, the anterior having formed the tragus, sufficiently well developed in the case under description, whilst the two posterior, arrested in their development, have produced the rudiment of the pinna, which still bears traces of subdivision. The deformity must then be compared to the ear of a fœtus of the second or third month. It is to be remembered that at this epoch the auditory aperture is limited by two lips, the posterior of which is divided into two unequal parts by a notch. The helix and antihelix are added later to these. In the case in question the pinna has been arrested in growth before these were formed, and the concha has also been twisted from the normal direction. Perhaps one of the most interesting points in the case is its well-marked hereditary character, the following being the family tree:—



In this table the capital letters represent the affected individuals, the

small those which were normal. In the bracketed male the deformity was only present on one side.

Branchial Fistulæ.

A paper on branchial fistulæ, of a lengthy and exhaustive nature, has been contributed by v. Kostanecki and v. Mielecki (8). They express the opinion that since there are no pervious branchial clefts in the embryo, but only as a rule outer branchial furrows and inner branchial pouches, congenital fistulæ cannot be looked upon simply as persistent branchial clefts. On account of the later alteration of position of the branchial arches, and of the formation of the sinus cervicalis and its subsequent closure by the opercular process, a reference of fistulæ to individual clefts on account of the position of their external opening is untenable. Remnants of the first inner branchial pouch exist in the Eustachian tube and the cavity of the tympanum, and of the first outer furrow in the external auditory meatus. In the case of the three succeeding furrows and pouches, if a complete fistula is to be formed, first the sinus cervicalis must remain open, and secondly an inner pouch must rupture into the sinus. Of the three pouches now under consideration, the third and fourth are, on account of the preliminary steps to the closure of the sinus, occluded. It is probable that only the second pouch, and especially that part of it which Rabl called the branchial passage (Kiemengang) breaks through into the sinus. Inner incomplete fistulæ may originate from any of the branchial pouches, though most of the pharyngeal diverticula do not belong to this category. Outer incomplete fistulæ owe their existence for the most part not only to the persistence of the sinus cervicalis, but also to the rupture into it of the second pouch, the pharyngeal opening being afterwards obliterated. To the category of incomplete outer fistulæ belong also those cases described as median fistulæ of the neck. It may be mentioned that Kanthack, in the last number of this *Journal*, has expressed his agreement with the authors in this opinion. It is obviously impossible to give any adequate account of a paper which runs through three numbers of *Virchow's Archiv*, but its completeness will be understood from the fact that it is concluded by a table in which are set forth in considerable detail the leading features of over 120 cases.—Poirier and Retterer (9) have published a paper on the examination of the cartilages from a case of bilateral persistent branchial cartilage. They were removed from the corpse of a woman aged forty years, in which they were placed at the anterior border of the sterno-mastoid and at the level of the crico-thyroid membrane. Each projected for 10 mm. from the surface, and was covered by thin pigmented skin; when removed the right measured 12 mm. and the left 15 mm. The larynx and pharynx, carefully examined, showed no deviation from the normal. A microscopic examination showed that each was covered by a layer of perichondrium, within which was a reticular or elastic cartilage, whose central part was in a higher stage of evolution, the peripheral part resembling fœtal cartilage. In fact the structure was that of the cartilages of the pinna.

A similar case has also been described by Bidder (10) which occurred in a child aged 8 months, in whom it was situated on the right side of the neck, at the anterior border of the sterno-mastoid muscle, and at the level of the thyroid cartilage. The tumour, which was situated under the skin, was removed by operation and then measured 1·7 cm. at its base, height 10 mm., and thickness 6–7 mm. Microscopically its structure was that of elastic fibro-cartilage.

Nervous System.

Meyer gives a description of an unusual case of basicranial hernia in *Virchow's Archiv* (II). Cerebral herniæ of the base of the skull are met with occurring between the body of the sphenoid and the ethmoid, passing through the body of the former, or finally through the position which the ethmoid should occupy. These are all of rare occurrence, but the first is the commonest of the three. The subject of the malformation was a female child, aged 3 days, from whose left nostril there protruded a tumour of the size of a hazel-nut, elastic to the touch. The tumour was removed, and about 6 weeks afterwards the infant died. The stalk of the tumour was, on examination, found to pass through an aperture 1·0 × 0·5 cm. in the left cribriform plate. The stalk of the tumour was connected with the under surface of the frontal lobe. A microscopic examination of the tumour showed that it was composed of mucous membrane, dura mater, arachnoid, and pia mater in superposed layers. In the interior it consisted of neuroglia, but no ganglion cells or nerve fibres were to be found. There was no cavity in the interior of the tumour or stalk.

Steffen has described (12) a case of spina bifida which possesses special features of interest. It was lumbar in situation, and occurred in a child 6 months old, the subject also of right pes varus. The tumour was about the size of a child's head. An operation was performed but the child succumbed. On opening the spinal canal the cleft was found to have been situated in the 5th lumbar vertebra. In the lower dorsal region the vertebral canal was divided into two portions by a bony ridge placed on the posterior aspect of the 11th dorsal vertebra, and at this point the spinal cord also divided into two portions, each of which was completely clothed with dura mater. The cord was in its entire length 18·5 cm., and terminated at the 4th lumbar vertebra. Its cervical portion was normal. The dorsal part was enlarged from the 4th to the 6th nerves, from the 9th it became thin and soon divided into two portions, at first connected to one another by connective tissue, but afterwards separated by the bony ridge above alluded to. Below the ridge the two portions re-united at the level of the 1st lumbar nerve to form a conus medullaris. Of the two halves that of the right side was the larger. From these cords no nerves were given off, and there was no cauda equina in any correct sense of the term. On cross section in the dilated portion of the dorsal cord, there was observed a spindle-shaped cavity which gradually enlarged to a diameter of ·75 cm., and engaged the greater part of the cord, so that only a small peripheral ring remained. A

second cavity was found in the right division of the double part. In the cervical region a cavity existed near the central canal and of double its size, which microscopic examination proved to be of a vascular nature. The spindle-shaped cavity in the undivided dorsal part of the cord proved to be a true dilatation of the central canal. As regards the two parts of the divided portion, the left was divided into anterior and posterior parts by two lateral fissures, and in the hinder part lay the central canal. The right side also had a central canal which lay near the periphery. Space will not permit of a fuller description of the microscopic appearances. This case is of special interest in connection with the paper by Sir G. Humphry (this *Journal*, July 1886) on spida bifida with bony projections into the spinal canal, and the note thereon in Prof. Cleland's *Memoirs and Memoranda on Anatomy*. On p. 161, he says, "I have sought for the explanation of these bony projections. Professor Humphry evidently suspects that they have a morphological significance, and in this he is undoubtedly correct. Their shapeliness, and in some cases their sequence and separate centres of ossification indicate that much. But I think further that those who read what is brought forward in this volume in the memoir on *Birds with Supernumerary Legs*, will scarcely find room to doubt that the bony projections in question owe their origin to partial fission of the early embryo. The precise nature of the fission may possibly vary in different instances. But as the anomaly in all the six cases recorded by Humphry has been in the lumbar region or lower end of the dorsal, the fission has most probably been abcaudal in them all." The case just described certainly appears to bear out this view.

In a paper on the experimental production of spina bifida, Richter (13) states his opinion, that his preparations show irrefutably that dropsy of the medullary tube has nothing to do with the etiology of spina bifida in fowls.

The subject of the condition of the spinal cord in anencephalus is dealt with by v. Leonowa (14). He concludes that several tracts are wanting in anencephalus, that those which persist are more or less subjected to micromyelia. The tracts which fail absolutely are the lateral pyramidal tract and the direct cerebellar tract. The white substance is best developed posteriorly. A remarkable decrease of ganglion cells is to be noted in the grey substance. It is to be observed that the wanting columns are in direct and immediate connection with the cerebrum and cerebellum, without the existence of which their development is impossible. The author also remarks that the absence of respiratory centre as proved by microscopic examination, coupled with the fact that the fœtus lived 17 hours and 20 minutes, suggests that, besides the ordinary respiratory centre, there must be another at present unknown which can on occasion and for a short time carry on the respiration. This careful study of the anencephalous cord contains a very minute account of the conditions, with numerous measurements, and deserves a longer description than it has been possible to allot to it in this place.

An account of the examination of the spinal cord in a calf of the

variety of double monstrosity known as dicephalus dibrachius has been published by Sperino (15). There were two distinct and separate heads, and two necks united to a single body with two upper and two lower extremities. There were two spinal cords, which were formed in an homologous manner, that is the inner half of the left was similarly arranged to the inner part of the right, and so also the outer parts. The description which is given relates to the left cord, but might be referred to either. A section in the lumbar region shows a remarkable assymmetry, the anterior fissure not occupying the middle line; but being displaced to the inner side. The posterior fissure was directed from the centre to the postero-external aspect, so as to form an angle with the anterior, instead of being in the same line. The elements of the inner half were all much less developed than those of the outer, the ganglion cells being much fewer in number. The posterior column of the inner side was much smaller, and presented the essential peculiarities of the column of Goll only, whilst in the outer larger segment both Goll's and Burdach's columns could be distinguished. In the dorsal region the two halves presented a much less assymmetrical appearance, the constitution of the two sides not differing very much. In the cervical enlargement, the assymmetry reappeared though not to so great an extent as in the lumbar region.

Absence of Pectoral Muscles.

To the list of cases of this defect three have recently been added. Pulawski (16) describes an instance of a man aged thirty-six, in whom there was also a deficient formation of the ribs of the right side. The ascending part of the 6th rib was attached to the sternum at a sharp angle. The 5th rib had no cartilage, but was attached to the 6th. The 4th rib ended blindly in a rounded thickening 4·5 cm. from the sternum. The 3rd and 2nd ribs, which were very small and thin, ended blindly like the false ribs. The 1st appeared to be normally formed. As regards the muscles the clavicular part of the pectoralis major was present, but the remainder of that muscle as well as the pectoralis minor and the serratus magnus were absent.—In the case given by Sklodowski (17) the patient was aged twenty years. The sterno-costal portion of the pectoralis major together with the pectoralis minor were absent on the right side. Associated with this malformation was a defective formation of several of the fingers of the right hand, the index and medius consisting of only two phalanges, the annularis having immovable joints and all the interdigital spaces being webbed.—Ruckert (18) also describes a case, in which, in the body of a five days' old child the subject of hereditary syphilis, the sterno-costal part of the pectoralis major, the whole of the pectoralis minor, and the middle portion of the serratus magnus were absent on the left side. Dissection showed that the branches of the acromio-thoracic axis and the two anterior thor-

acic nerves were present as usual, which the author thinks proves that the defect cannot be accounted for either by the theory of deficient vascular or nervous supply.

Defects due to the Amnion.

Chavane (19) describes a case in which an amniotic band caused a deep cleft in the face and palate, extending from the external angle of the orbit on the left side into the mouth, whilst on the right the fissure passed from the mouth to the centre of the lower eyelid. The amniotic band was attached to the meninges above. The palate was also divided by its agency.—The subject of intra-uterine amputations, respecting which so many diverse theories have been advanced, is dealt with in two communications in the *Bulletins de la Société Anatomique de Paris.* In the first Thérese (20) describes the case of a six months' fœtus, in which there was a complete amputation at the upper third of the left leg. The fingers of the left hand were syndactylous, the cone which they formed by their union being surmounted by a long fibrous filament, and each digit wanting its last phalanx. The upper extremity of the right side was normal, but the lower showed numerous deficiencies. The last phalanx of the 3rd and the 4th toes had disappeared, and two deep furrows had partially detached the 1st toe and the extremity of the 2nd. There were also on the same limb, at the lower part of the leg, two deep grooves, about 1·0 cm. distant from one another. In the discussion which followed Broca expressed his opinion that these lesions were due to the constriction of amniotic bands, rejecting the views that such defects could be produced by sclerosis. At the next meeting of the Society the last-mentioned observer (21) brought forward another case of the same kind, where the foetus was affected by very numerous intra-uterine amputations, by encephalocele and by a complicated form of cleft palate.

Tumours of the Umbilical Cord.

Kaufmann (22) contributes a case to the scanty literature of this subject. In this instance the tumour was of firm consistence and almost spherical in shape, measuring 16 cm. in diameter. It was attached to the cord close to the abdomen, to which indeed its base was connected. The microscopic examination of the tumour showed that it consisted in part of numerous branching and partially cavernous vessels, and in part of myxomatous and embryonic tissue, the author describing it as a myxosarcoma telangiectodes. Amongst the few cases of tumours of the umbilical cord which have been previously described there is one of special interest recorded by Budin some two years ago, in the *Archives de Tocologie.* In this instance the cyst was situated 8 cm. distant from the umbilicus, was filled with fluid, and presented on microscopic examination all the features of a dermoid tumour, possessing an

epithelial lining, with hairs, sebaceous glands, smooth muscular fibres, nerves, cartilaginous nodules, &c. The compiler of this report had once the opportunity of examining a similar tumour which was found on the umbilical cord of an anencephalous fœtus. The fœtus was received in a condition which did not permit of a microscopic examination, but so far as could be made out, the appearances were very similar to those of the tumour just described.

Miscellaneous Papers.

The following papers of interest deserve brief mention:—A case of cyclops arrynchus recorded by Angerstein (23) as occurring in a sheep.—An example of diaphragmatic hernia is recorded by Gauthier (24) occurring on the left side. The vena cava traversed its own opening, but the aorta and œsophagus passed through the aperture in the diaphragm, which transmitted the hernia.—An instance of complete transposition of the viscera in a female aged sixty years is described by Sperino (25).—Rauber (26) figures and describes a man, aged thirty-eight years, in whom the penis is completely absent. The scrotum and testicles are present and well formed. The urethra opens on the anterior wall of the rectum, through which urine is passed, and into which, apparently, seminal emissions from time to time occur.

A case of cleft palate of the type described by Albrecht as normal is recorded by Sabouraud (27).—Hélary (28) describes a tumour of nearly the size of a fœtal head at full term, removed from the right side of the neck of a child aged six months. It was vascular in its nature, consisting of arteries, veins or vessels of indeterminate nature resembling veins and capillaries. The tumour was about half the size mentioned above at the time of birth.—Jöel (29) records a case of a boy, fourteen years of age, in whose body was found attached to the pulmonary artery, and within the pericardium, a tumour of the size of a hen's egg, which was teratomatous in its nature.

The compiler of this report will feel much obliged to authors who may forward to him reprints of papers dealing with teratological subjects, for use in the preparation of similar reports in the future.

References.

(1) *Corrbl. der deutschen Ges. für Anthropologie*, Nov. 1888.
(2) *Ib.*, March 1889.
(3) *Ueb. die Hypothese einer Vererbung von Verletzungen*, 1889.
(4) *Virchow's Archiv*, Bd. cxix. hft. 2.
(5) *Arch. für Anthropologie*, Bd. xviii. hft. 4.
(6) *Arch. für Anat. und Entwick.*, Jahrg. 1890, s. 295.
(7) *L'Anthropologie*, T. i. No. 5, p. 580.
(8) *Virchow's Archiv*, Bd. cxx. hft. 3, s. 385; Bd. cxxi. hft. 1, s. 87. hft. 2, s. 247.
(9) *Journal de l'Anatomie et de la Physiologie*, 1890, No. i. p. 19.
10) *Virchow's Archiv*, Bd. cxx. hft. i. s. 194.

(11) *Ib.*, cxx. hft. 2, s. 309.
(12) *Jahrb. für kinderheilk*, Bd. xxxi. hft. 4, s. 428.
(13) *Verhandl. der anatomischen Gesellschaft*, 1888, s. 159.
(14) *Arch. für Anat. und Entwick.*, Jahrg. 1890, s. 403.
(15) *Internat. Monatsschrift für Anat. u. Phys.*, 1890, Bd. vii. hft. 10.
(16) *Virchow's Archiv.*, Bd. cxxi. hft. 3, s. 598.
(17) *Ib.*, *Ib.*, s. 600.
(18) *Münchener Medicin. Wochenschrift*, 1890, No. 27.
(19) *Bull. de la Soc. Anat. de Paris*, 1890, No. 5, p. 137.
(20) *Ib.*, No. 19, p. 473.
(21) *Ib.*, *Ib.*, p. 476.
(22) *Virchow's Archiv*, Bd. cxxi. hft. 3, s. 513.
(23) *Berl. Thierärztl. Wochenschrift*, 1890, No. 46.
(24) *Bull. de la Soc. Anat. de Paris*, 1890, No. 21, p. 533.
(25) *Giornale della Reale Accad. di Med.*, 1890, No. 6.
(26) *Virchow's Archiv*, Bd. cxxi. hft. 3, s. 604.
(27) *Bull. de la Soc. Anat. de Paris*, 1890, No. 12, p. 270.
(28) *Ib.*, No. 18, p. 459.
(29) *Virchow's Archiv*, Bd. cxxii. hft. 2, s. 381.

THE MINUTE ANATOMY OF THE SPINAL CORD AND CEREBELLUM DEMONSTRATED BY GOLGI'S METHOD.

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A. THE SPINAL CORD.

THE method employed by Golgi,[2] which has added so much that is new to our previous knowledge of the microscopic anatomy of the central nervous system, has been modified by Kölliker, as follows:—The spinal cord, with the brain attached and held together by the dura mater, is removed; the dura is then incised, and the whole cut into pieces of 3–4 mm. long. The pieces which are held together by the membrane are placed in the following mixture:—bichromate of potassium (3 per cent.) 4 parts, perosmic acid (1 per cent.) 1 part, a sufficient quantity of the fluid being used so as to give to each piece from 40 to 50 cubic centimetres. The solution is changed after several hours. After the pieces have remained in this (solution) from 1 to 1½ days they are removed and washed for a quarter to half an hour in ¼ per cent. solution of nitrate of silver, and are then placed in a considerable quantity of ¾ per cent. nitrate of silver solution for 30–40 hours. From this they are removed to 40 per cent. spirit, in which they can be preserved for some time; but they tend to become spoiled if kept in the spirit for more than three to six weeks. On removal the pieces are ready for cutting by the hand, or better still for imbedding. For this purpose they are placed in absolute alcohol for one hour, and then in celloidin for an hour. They ought then to be cut at once; since they spoil after waiting one day. The sections are clarified in kreasote for a quarter of an hour, transferred to turpentine, and mounted in xylol balsam.

The action of silver upon the elements of embryo cords, and those of young animals, is to stain the neuroglia and nerve cells, and to bring into prominence all nerve fibres, which as yet possess no nerve sheath and exist as naked axis cylinders. It is to this circumstance that preparations made from embryos owe their great value, for by them one can follow out the relations of nerve

[1] *Zeitschrift für wissenschaftliche Zoologie*, Band xlix. Heft iv. and Band li. Heft i., 1890.

[2] The references to Golgi's works are:—1. *Studi istologici sul midollo spinale*, Milano, 1881; 2. *Sulla fina anatomia degli Org. centrali del syst. Nervoso*, 1886. The original work was noticed in Hofmann and Schwalbe's *Jahresberichte*, Bd. x., but is so little known that its contents have not found their way into recent works on Anatomy and Histology.

fibres and cells at the same time. But in the same preparation all the elements are rarely equally well stained. Kölliker finds that the nerve fibres and their branches stain most readily, so that one sometimes sees sections in which, to all appearance, there are no nerve or glia cells. When these latter exist, they are present most frequently as the so-called epithelial cells of the central canal, in the neighbourhood of the posterior median fissure, and in the superficial portions of the posterior columns. With regard to the nature of the silver-stained elements, it is to be observed that, without exception, the non-medullated fibres are of extreme delicacy, and perfectly smooth-walled, so that they cannot owe their staining to the laying on of silver. In the white columns they measure 1–2 micromillimetres, while in the grey matter they are so delicate as to be immeasurable. Many nerve fibres are of equal breadth throughout their course, while others present greater or smaller varicosities, and this occurs in the stem fibres as well as at their very terminations. There are especially to be observed small triangular swellings, which are very frequent where the branches are given off. The nerve cells are rarely stained perfectly clean, often showing irregularities which are due to precipitation of silver outside; and this occurs still more frequently in neuroglia cells.

1. *The Posterior Roots and Posterior Columns.*

The posterior nerve roots enter the cord by numerous small bundles which gently ascend in the postero-lateral groove; and turning mesially towards the posterior columns, each fibre divides into two portions, an ascending and a descending. In men and pigs this division takes place at angles of 150° or 160°, and as the fibres of a root bundle split at the same level, and the divisions retain their oblique course for a long time, the superficial portions of the posterior column present a peculiar and characteristic arrangement of fibres. In their further course these fibres extend into the deeper parts of the column and become longitudinal fibres. When examined more closely, the posterior roots are found to sink into the region of the lateral segment of the substantia gelatinosa in the part of the posterior column recently called the border tract [Randzone] of Lissauer. Here the root bundles divide into two systems, a smaller lateral one, which passes towards the postero-lateral corner of the substantia gelatinosa, and a stronger stouter median one, which courses in the border tract towards the posterior column. In the lateral system all the root fibres divide at the same place; in the median they diffuse over the whole space between the entrance of the roots and the posterior column, occupying in antero-posterior diameter the ventral part of the border tract, while the dorsal portion is formed by a border of longitudinal fibres. The divisions are here scattered over a considerable area; and the ascending and descending fibres which are given off from these so intertwine amongst each other, that in cross

sections a very delicate alternation of small bundles of fibres exists. As a result of his investigations on the spinal cords of human embryos, as well as on those of sheep and new born kittens, Kölliker is inclined to believe that all the sensory root fibres divide.

It is important to consider now the further course of the branches of the sensory roots, and to find out definitely how they end. The posterior columns, by which are meant not only the usual so-called columns, but also the connected layers of white matter which are situated outside the substantia gelatinosa and connect the posterior and lateral columns, are essentially composed of the fibres of the posterior roots.[1] The longitudinal fibres of the posterior columns bend at a right angle and pass into the substantia gelatinosa, where they break up into fine branches (in the spongy substance), and behave in a manner similar to what is later on described as occurring in the "collaterals" of the column fibres. These bendings are not abundant all over, and it is impossible to say whether they are only in the descending or also in the ascending fibres. Some are true terminations, and divide in the posterior horn into delicate branches, others are longitudinal fibres which turn back in the substantia gelatinosa by another bending to their former course. It is difficult to say how many of the branches of the posterior root fibres pass into the grey substance to end there, and how many pass up to the medulla oblongata. It is most probable that all the descending branches pass into the grey substance, and that the ascending mostly pass up to the brain. Kölliker believes also that these latter may partly enter the grey substance, as he has observed in longitudinal sections that some of the fibres entered the grey matter at right angles and ended there. Observation of many sections further shows that a great number of the fibres of the posterior columns run a very considerable distance without interruption.

It is of interest to notice if this method throws any light upon the vexed question of the origin of the sensory roots in cells of the grey matter of the cord.[2] The observations of Golgi, Ramón y Cajal,[3] and Kölliker cannot confirm this statement; none of them has ever seen a nerve cell passing into a sensory root fibre. Until further proof is forthcoming for the higher animals, it is well to teach that

[1] It is essential to remember that the posterior horn and substantia gelatinosa is of extraordinary breadth and thickness in the embryo. As growth proceeds, the grey matter, which at first prevailed, gradually gives place to the white.

[2] The evidence in support of this view is briefly that Kutschin, Freud, and Klausner have observed in Petromyzon and Proteus a certain number of sensory roots springing from cells in the grey matter; while Joseph has found experimentally that, in cats, by section of the posterior roots proximal to the ganglion at the second cervical nerve, several fibres degenerate. If the nerve is divided beyond the ganglion all the fibres degenerate, which shows that several fibres have their trophic centre in the cord.

[3] Ramón y Cajal (of Barcelona) has elaborated Golgi's method and confirmed his observations; the references to his works are:—1. *Rivista trimestrial de Histologia*, Marzo, 1889; 2. *La medicina practica*, 1889; 3. *Nuevas observ. s. l. estructura de la Médula espinal de los Mamiferos*, 1890 (from the Laboratory of the Faculty of Medicine of Barcelona).

the origin of the sensory root fibres in the cord cannot be held as proved.

2. *The Collaterals (Collateralen) of the Posterior Roots and Posterior Columns.*

The existence of lateral branches (collaterals) of the longitudinal fibres of all the columns of the spinal cord is the most important discovery of Golgi and Ramón y Cajal. They are very readily seen in longitudinal sections, and are a noteworthy feature of the minute structure of the cord, and form one of its most important physiological relations. As a rule they are not so thick as the longitudinal fibres, and like them they present varicosities, especially on their fine ramifications and at their terminations, which, according to Kölliker, are artificial. The collaterals are usually given off at acute angles, but in some cases they arise from the stem fibre at a right angle.

All collaterals end in small *terminal bushes or tufts*, which remind one of simple end plates. These small tufts consist of numerous short twigs of the finest varicose fibrils, which encircle the bodies of nerve cells, and mainly end in fine knobs. When the cells are large, as in the anterior and lateral horns, these twigs form very beautiful pictures, and one notices that there are no anastomoses of neighbouring twigs, and that they are not in direct association with the cells. Similar endings are found in the substantia gelatinosa, substantia spongiosa, and in Clarke's column. As at their terminations the collaterals show no sign of anastomosis in their course.

We will now consider in detail the collaterals of the sensory roots and their branches and of the posterior columns. After the sensory roots have entered the border tract, they give off in certain cases before their division single lateral branches. Similarly the fibres of the border tract and posterior column give off collaterals. The number of collaterals given off is very great, varying from two or three up to nine in very long fibres, and they follow each other at greater or less distance. They occur in all parts of the cord, both in the limb enlargements, in the intervening portions, and in the upper cervical region, and so many are there that it is difficult to see a fibre which does not give them off. In all portions of the posterior columns, superficial, middle, and deep collaterals are present; it is therefore reasonable to conclude that the majority of the fibres of the posterior column give off collateral branches. It is, however, worthy of note that in many preparations the collaterals are less well or not at all stained. In the dorsal corner of the posterior column of the cervical cord of a calf embryo, Kölliker noticed a small compact bundle which possessed no collateral fibres, while they were well formed in all the other portions of the column.

The sensory collaterals, as the lateral branches of the posterior column fibres may be called, pass from the different portions of the column into the grey matter of the posterior horn, and course more or less towards its ventral or motor parts, in order to terminate in its

different regions, and even in the anterior horn of the same side. Their passage into the grey matter is in bundles of five, ten, fifteen, or more fibres, which enter partly in a straight course, and partly arched and slanting through the substantia gelatinosa. The place and nature of their termination is important—

1. In the substantia gelatinosa in the manner described above as characteristic of collaterals.
2. In the boundary layer between the substantia gelatinosa and spongiosa; here the fibres are numerous, and form a delicate felted arrangement.
3. In Clarke's column, where they form a network similar to that in 2.
4. In the substantia gelatinosa of the opposite side. In some growing animals a posterior commissure is found to exist and to be composed of collaterals. Ramón y Cajal describes the posterior commissure in new-born dogs as consisting of three parts: anterior and posterior arching bundles, and a middle transverse portion. The anterior bundle has its concavity towards the central canal, and consists of delicate and coarse fibres, which spread out laterally in all directions. The origin of these fibres is doubtful. The posterior bundle has its convexity to the ventral side, and consists of the collaterals of the posterior columns, which end in the opposite side in the adjoining portions of the substantia gelatinosa. The middle (a cross-running bundle) goes midway through Clarke's column, and ends in the lateral part of the substantia gelatinosa. The elements of this part of the commissure arise partly in the collaterals of the lateral columns, and partly their origin is doubtful.
5. In the substantia spongiosa of the posterior horn of the same side.
6. In the anterior horn. There is a very important group of the sensory collaterals which penetrate the anterior horn of the same side, called by Ramón y Cajal the "antero-posterior" or "sensori-motor" group. Springing partly in the posterior column and partly in the border tract, they collect in the substantia spongiosa into stout bundles, and penetrate as compact strong fibres straight into the anterior horn, where they spread to all parts, and end in the region of the nerve-cell groups in the finest branches. These are defined by Kölliker as the reflex collaterals of the sensory roots.

3. *Collaterals of the Anterior and Lateral Columns.*

The collaterals of the lateral column fibres pass partly into the ventral portion of the posterior column and of Clarke's column, and partly into the anterior horn to the various motor cell groups. Some single fibres pass into the boundary region between the substantia gelatinosa and spongiosa and towards the white commissure. The collaterals of the anterior columns all pass dorsalwards, some cross into the commissure, others towards the anterior and lateral horns of

the same side, while others still go into the posterior columns. These latter form end bushes, which remind one of the long sensory collaterals, and are most perfectly recognised in sagittal sections. Concerning the end ramifications of these collaterals, Kölliker found, what he had not previously noticed in the sensory ones, long dependant branchlets, which give off on both sides, at nearly a right angle, a great number of short branches, which end as above described. Many of these collaterals only show such divisions, but others are in all respects similar to the sensory ones.

The anterior commissure consists partly of axis cylinders, which decussate, and partly of collaterals of the anterior and lateral columns, which often show branchings in the commissure and end in the grey matter of the opposite side, where they partly spread out into the anterior horn and partly turn towards the posterior horn. It is not impossible that among the last-mentioned fibres posterior column collaterals exist, which pass through the commissure to the opposite side.

4. *Nerve Cells.*

The cells of the grey matter of the spinal cord are all multipolar, but differ essentially, in that (1) some possess one unbranched or only sparsely-branched nerve process, (2) while in others this gives off numerous branches; this latter set are again divided into two subclasses: (*a*) those in which the axis-cylinder process, in spite of its giving off branches, does not lose its individuality; and (*b*) those whose axis-cylinder process divides into delicate and very fine ramifications. According to Golgi's classification, the cells of the first category and of (2) (*a*) are motor, while those of (2) (*b*) are sensory.

Another classification of nerve cells is based on physiological grounds, and is as follows:[1]—(*a*) *Motor Cells*, which pass into the motor root fibres or give origin to the same. These cells lie in the anterior horns and form nerve-cell groups; they are as a rule large, but may be small, especially in the median part of the ventral segment of the anterior horn, and in the region between the anterior and posterior horns. The nerve process of these cells goes usually straight towards the exit places of the roots, but others are arched. It is most probable that these fibres are not branched, although Ramón y Cajal mentions that he once saw in a rat a lateral branch of such a fibre coursing backwards. Golgi also describes such. It is yet doubtful whether these are constant or only in single cases. This point is of great importance physiologically, and the simplest explanation of such a branch is that a motor cell may in certain cases branch out into centrifugal fibres.

(*b*) Cells whose nerve process is transformed into a longitudinal fibre of the white matter [Strang-zellen—column fibre cells]. They can be subdivided into (1) cells whose process remains on the same

[1] The examination of the axis-cylinder processes of the cells of the cord is one of very great difficulty, owing to the fact that by the Golgi method all the cells are rarely stained.

side of the cord, (2) cells whose process passes by the white commissure on to the opposite side [Kommissurenzellen of Ramón y Cajal]. The great majority of these cells send their nerve processes into the lateral columns, many also into the anterior; the former lie mainly between the central canal and the projecting median corner of the lateral column; the latter are especially related to the median cell group of the anterior horns. The nerve processes of these cells partly possess no branches; in many cases, however, they give off a great number of branches without losing their individuality. The manner of ending of the stem fibre of the nerve process is noteworthy. In the majority of cases, as Golgi first saw, the end of the stem fibre bends nearly at a right angle into a column fibre. Kölliker considers all as nerve fibres which bend out of the longitudinal columns into the grey matter at a right angle, especially if they show no diminution in their diameter, and if they cannot be followed up to a nerve cell. Secondly, the stem fibre ends by dividing, forkwise, into ascending and descending column fibres, just as the sensory roots do at their entrance. And, lastly, there remain a few processes, whose relation in the white substance is not yet settled, whether they pass away in one or in divers directions.

According to Golgi and Ramón y Cajal, all the nerve processes of this category pass into column fibres. In a preliminary communication Kölliker believed that those which crossed in the anterior commissure passed into the anterior roots of the opposite side. As he has been unable to find a relation between the commissure fibres and the nerve roots, he has no reason to hold this opinion any longer.

(*c*) Cells whose nerve processes give off branches right up to their terminations, but do not pass beyond the grey matter. These were first described by Golgi, and appear to exist only in the posterior horns, but not exclusively. They are most marked in the neighbourhood of the point of the posterior horn, but have also been found at the dorsal border of the substantia gelatinosa and in other parts.

Especially important for the interpretation of these cells was the nature of the termination of their branches. Golgi and Ramón y Cajal noted that they ended free and with varicose branches; none of them end in tufts or bushes, as is so characteristic of collaterals.

For accounts and figures of the manifold forms of nerve cells and of their protoplasmic processes, the reader is referred to the works of Ramón y Cajal. It is necessary, however, to say that it is very difficult to define the protoplasmic processes of these cells. When one remembers that these branches are perfectly smooth, the pointed and granular appearance which they present, and which makes them resemble neuroglia cells, is probably artificial. Regarding these processes the following may be noted :—in silver preparations they form numerous coarse ramifications, so that in the organs of the new-born many cross through the whole breadth of the grey matter, and occupy half of its antero-posterior diameter. The median group of cells of the anterior horn are peculiar in that they send a portion of their branches through the anterior commissure to the opposite side—a relation which Ramón y Cajal first pointed out, and which Kölliker

finds also in the cells in the neighbourhood of the posterior commissure. Some protoplasmic processes enter the white columns, and often penetrate right through to the surface of the cord.

5. *Neuroglia Cells.*

These consist of the elements of the original medullary plate, and are divided into primary and secondary groups. The first appear as the epithelium of the central canal, and originally pass through the whole cord, but later on are only present in the deeper parts; the latter arise later in all parts of the grey and white substance, likewise from the elements of the medullary plate.

Summary.

1. The sensory root fibres divide at their entrance into the cord into an ascending and descending branch.

2. Some of these sensory fibres course for a considerable distance (4–6 cm.) longitudinally; others arch into the grey matter, and end free in delicate ramifications.

3. An association between the sensory root fibres and the cells of the grey matter of the cord has not up to the present been observed.

4. All sensory longitudinal column fibres give off delicate lateral branches—the so-called *Collaterals* of Ramón y Cajal, which, entering the grey substance, ramify in all its parts and end free.

5. The motor root fibres arise from greater and smaller nerve cells of the anterior horn in a single nerve process, which in certain cases (always, according to Golgi) give off lateral branches.

6. The anterior and lateral columns consist partly of fibres, which are given off by nerve cells in all parts of the cord. These column fibre cells (Strang-zellen) give off from their axis-cylinder process a greater or less number of lateral branches into the grey substance, which end free.

7. The relations of the nerve processes of the anterior and lateral column cells to the fibres in the white substance varies. In some cases they simply bend upwards and pass into a column fibre; at other times they divide into two or three branches; or, again, such a nerve process splits into an ascending and a descending fibre, or apparently attaches itself laterally to a column fibre (the T-shaped fibres).

8. The great majority of the fibres of these columns give off collaterals, which enter the grey matter of the anterior horn and of the anterior part of the posterior horn, and there end free, just as the sensory collaterals do.

9. The anterior and lateral column fibres bend in many cases at a right angle into the grey substance, and there end free.

10. All collaterals of column fibres, and all lateral branches of axis-cylinder processes end in the same way. They give off at acute or right angles a greater or less number of branches, and

finally form delicate end bushes, which encircle nerve cells without associating themselves with them on forming any anastomoses.

11. The anterior commissure consists of:—

a. Axis-cylinder processes of nerve cells of the grey matter, which, after decussating, are continued as longitudinal fibres of the anterior and antero-lateral columns.
b. The decussating collaterals of the anterior and lateral columns.
c. The decussating protoplasmic processes of a part of the median cells of the anterior horn.

12. The posterior commissure consists of:—

a. The decussating collaterals of the sensory root fibres.
b. Possibly of the decussation of the collaterals of the posterior part of the lateral columns.
c. Decussations of the axis-cylinder processes of cells placed laterally to the central canal and substantia gelatinosa (Ramón y Cajal). But this is very doubtful.
d. Decussations of the protoplasmic processes of cells of the posterior horns. This also is not quite ascertained.

13. The nerve cells are divided into:—

a. Motor cells (*vide* under 5).
b. Column cells (*vide* under 6).
c. Cells, whose axis-cylinder process does not go beyond the grey matter, and forms delicate ramifications in this. These only exist in the posterior horn.

14. The value of the size, shape, and character of the nerve cells is not fully known. It is at any rate certain that large nerve cells are not limited to the motor sphere only.

15. The protoplasmic processes of all nerve cells ramify over a great extent in all directions, often penetrate the white matter, give origin to no nerve fibres, and do not anastomose.

B. The Cerebellum.

Our knowledge of the minute formation of the cerebellum has, through the examinations of Golgi, made a great step forwards, and a new epoch may be said to date from them. In view of the confirmation by Kölliker of these most recent observations, we will briefly indicate what Golgi noted.[1]

1. *Purkinje's Cells.*—Golgi's method showed for the first time the excessively rich ramifications of the so-called protoplasmic processes of these cells, and proved that they formed no anastomoses with each other. He believed that the most superficial of these branches were attached to the connective tissue at the margin of the molecular layer and to the vessel walls. He further made the very important discovery concerning the axis-cylinder processes of these cells, viz., that they gave off a certain number of lateral branches, which partly

[1] *Sulla fina anatomia degli organi Centrali del Sistema nervoso*, 1886, p. 64.

coursed back into the molecular layer and partly spread out into the granular layer.

2. *The Small Cells of the Grey Molecular Layer.*—Contrary to the statements of many authors, this method definitely showed that these cells existed throughout the whole thickness of this layer in not inconsiderable numbers, and possessed, besides anastomosing branches, an axis-cylinder process which formed very delicate ramifications and coursed in very diverse directions, amongst which the horizontal was especially conspicuous. The end of this process was not seen.

3. *The Small Cells of the Granular Layer.*—Golgi first definitely pointed out that these were nerve cells. Their axis-cylinder processes are very slender, still lateral branches are occasionally found, and anastomoses of these processes with nerve fibres. The protoplasmic processes only divide very sparely, are short, and appear to end in small granule heaps (Körnerhaufen).

4. *The Large Cells of the Granular Layer.*—In human beings these exist as spindle-shaped bodies, and are characterised by the extraordinarily numerous ramifications of their axis-cylinder processes.

5. With regard to the *medullated nerve fibres,* Golgi showed that many ramified in the white matter, but especially in the granular and molecular layers, so that their very terminations showed a thick plaiting, the details of which it is impossible to follow out. These anastomose with—(1) The axis-cylinder processes of the small cells of the granular layer; (2) the lateral branches of those of Purkinje's cells; (3) the nerve processes of the small cells of the molecular layer. As the most characteristic part of this plaiting Golgi portrays those parts which lie at the boundary of the granular and molecular layers, and which present many coarse and fine horizontal elements.

Next to those of Golgi come the important observations of Ramón y Cajal,[1] who used the rapid hardening method with bichromate of potash, osmic acid, and silver.[2] The most important of these observations, illustrations of which were shown at the Anatomical Congress in Berlin, October 1889, are briefly as follows:—

1. *The Small Nerve Cells of the Stratum Granulosum.*—The branched processes of these cells end in small tufts of closely-set short branches; the axis-cylinder processes ascend, without exception, into the molecular layer and form in this delicate longitudinal elements, running parallel to the convolutions. In this layer they divide at different levels at right angles into two longitudinal fibrils, ·2 to ·5 micromillimetre long, which after a course of ·2 to 1 millimetre end free without branching.

2. *Small Nerve Cells of the Molecular Layer.*—The most noteworthy facts discovered by Ramón y Cajal upon these elements are that the axis-cylinders of all the cells lying near the granular layer form peculiar branches or baskets which encircle the bodies of Purkinje's cells and form holes for them.

[1] Ramón y Cajal. *Rivista trimestrial de Histologia Normal y pathologica,* August 1888 and Marz 1889.

[2] This method is described under the description of the spinal cord.

3. In the cerebellar cortex he found also specially branching fibres, which passed from the granular into the molecular layer and which he divided into three kinds :—

(*a*) Fibres which passed from the granular into the molecular layer and ended there in a branched expansion. He was able to follow these fibres in some cases into the white matter.

(*b*) Fibres which, arising in the white substance, ramified in the granular layer, and showed in their course mossy appendages. These are the "Fibras musgosas" of Ramón y Cajal. The very terminations of these fibres, each of which possesses from 20 to 30 branches, are on the level of Purkinje's cells, and appear to pass over into longitudinal fibrils. He is inclined to construe these fibres as the sensory terminations of the axis-cylinders of peripheral nerves, and bases this hypothesis on these two facts :—(1) The optic nerve in birds ends in the lobus opticus in free branches; and (2) the sensory root fibres in the cord course in a similar way.

(*c*) Fibres which, ascending from the granular layer, end in nests which encircle Purkinje's cells. These are the "Nidos cerebellosos."

4. Concerning the cells of the cerebellum described by Ramón y Cajal, in addition to those facts mentioned above, are the following :—

a. The axis-cylinder processes of Purkinje's cells have processes which pass back into the molecular layer.

b. The axis-cylinder process of the large cells of the granular layer is extraordinarily richly branched.

5. Ramón y Cajal mentions no branches in connection with the medullated fibres of the cerebellum. Concerning the question which of the fibres (which are shown by Golgi's method) are medullated, he surmises that possibly the very terminations of the "fibras musgosas" may be, and also the branches of the axis-cylinder process of Purkinje's cells which bend into the molecular layer, for both of these sets may become the medullated longitudinal fibrils of the molecular layer. As non-medullated, Ramón y Cajal considers the axis cylinders of the granular cells, those of the small cells of the molecular layer, and of the larger granular cells.

Since the recent observations of Ramón y Cajal upon the cerebellum have not yet been confirmed, and even those of Golgi have only been re-examined by a very few, it will not appear superfluous if I communicate the results of Kölliker's own observations upon the minute structure of the cerebellum.

1. *The Small Nerve Cells of the Granular or Rust-coloured Layer, or the Small Granular Cells* (Körnerzellen).

The examination of these cells has only been made in cats, and in preparations which have been treated both by Golgi's long method and by the short bichromate of potash, osmium, and silver method. In both forms of preparations, but especially in the first, these nerve cells were found, as Ramón y Cajal described, to possess short protoplasmic and long axis-cylinder processes. The former averaged from

10–40 micromillimetres in length, were simple, and appeared to end in short branches; the latter sprang usually from one of the other processes, only seldom from the body of the cell, and penetrated with a serpentine course outwards into the molecular layer. In such preparations only single small granular cells are stained, so that they are easily followed in their entirety; yet one finds places at which two, three, or more cell-bodies are grouped together, and from which a great number of typical nerve and ramifying branches go off. It is not difficult to follow the fragile nerve-processes right into the molecular layer, and to prove that they are here transformed into longitudinal elements after they have divided into two branches, each of which forms a right angle with the stem. These longitudinal fibrils here and there apparently end free; but it ought to be emphasised that the free endings are possibly not such, for it is impossible to say whether the silver has stained them throughout their whole length. The number of these fibrils is very considerable, and longitudinal, oblique, and tangential sections of the convolutions show them in the form of a very thick and delicate striation of fibrils, some of which are varicose and tortuous, and pass through the whole thickness of the molecular layer to its most superficial parts. On cross sections of the convolutions these elements appear as fine dots or streaks, which fill in the intervals between the ramifications of Purkinje's cells.

In exceptional instances this longitudinal fibre-system has special relations. Kölliker agrees with Ramón y Cajal, firstly, upon the presence of branches to the oblique stem fibres within the molecular layer, which become longitudinal fibrils; and, secondly, upon the appearance of ostensible stem-fibres, which pass over at a right angle into only one longitudinal fibre. Ramón y Cajal thinks that such a fibre could represent the termination of a longitudinal fibre, and, since he never saw it in association with a small granular cell, but followed it well up to the white matter, could pass into a medullated fibre.

The following facts may be added regarding these longitudinal fibres:—They stain most readily in the innermost parts of the molecular layer, and seldom throughout its whole thickness. Further, the staining is only partial, so that, between large and small bundles, streaks exist in which none of the fibrils are stained.

Are these longitudinal fibres and the nerve processes of the small cells of the rust-layer medullated? Ramón y Cajal does not think so; but this question will be more fully discussed later on, when we describe the medullated fibres of the small brain.

2. *The Large Multipolar Cells of the Rust-coloured Layer.*

These cells which have been discovered by Golgi have been confirmed by Ramón y Cajal. Their nerve processes form very rich ramifications. Kölliker saw them in cats and in the embryos of pigs and puppies, and, in contrast to those just described, he calls them the large granular cells. They are far smaller than Puriknje's cells,

and lie either at the outer margin of the granular layer, partly almost on a level with Purkinje's cells, and partly in the middle of the layer, or even at the inner boundary up against the white matter. From an angular cell body there pass towards different parts three up to six or more branching processes, which course partly between the granules and partly pass into the molecular layer, and can often be followed far outwards in this layer; but besides they can penetrate into the white matter, as was once observed in the deeper parts of the cerebellum.

3. *The Nerve Cells of the Molecular Layer.*

The nerve cells of this layer are divided into two sets, the large and the small, of which the former are situated in the deeper and the latter in its superficial parts. While this last possess the usual form of multipolar nerve cells, the former present a very strange disposition of nerve processes, which, as Golgi and Ramón y Cajal pointed out, course transversely for a certain distance in the region between the molecular and granular layers. This transverse fibre gives off, at right angles, processes which encircle as in a basket the bodies of Purkinje's cells. The bodies of the cells measure from 20 to 25 micromillimetres. and are usually drawn out longwise, and present four, five, or more angles. Besides the nerve process, they give off a large number of protoplasmic processes, which, mainly passing outwards, ramify in the usual way, and extend as far as the outermost parts of the molecular layer. The so-called nerve process of Ramón y Cajal is an altogether peculiar structure. Beginning very delicately at the body of the cell, it becomes in its horizontal and transverse course twice or four times thicker, and stretches over the bodies of Purkinje's cells in order to give off branches from place to place. These branches pass off obliquely, sometimes with a coarse, sometimes with a delicate root, and end in such a way that each branch or branchlet is transformed into quite a tuft or pencil of terminal fibres, which encircle basketwise the bodies of Purkinje's cells.[1] To unravel them further is a work of considerable difficulty, but it is probable that the branches have no association with each other, but end free. Likewise their relation to Purkinje's cells is not easy to ascertain. From transverse and longitudinal sections both parts appear to be only in juxtaposition, so that the baskets not only always closely embrace the cell bodies, but penetrate with single processes into the granular layer. It is important further to note that the pencil-like arrangement of branches of many cells participate in the formation of one basket. Kölliker confirms Ramón y Cajal's observations that a cell only possesses one process which lends itself to the formation of a fibre basket. Besides the descending branches which go to form the basket, the nerve processes of the cells in question give off here and there towards the surface

[1] Kölliker has applied distinctive names to these structures. The basket or pencil arrangement of fibres he has called *Faserkörbe* and *Faserpinsel* respectively. The cells he has called basket cells (*Korbzellen*).

of the molecular layer processes, which behave as ordinary protoplasmic processes.

The cells which participate in the formation of the above described fibre basket, and which for simplicity's sake should be called basket cells (Korbzellen), belong, as has already been remarked, to the deeper parts of the molecular layer. The number of these elements corresponds to the number of Purkinje's cells, and is therefore sparse in the region of the furrows. Still there may be other variations in the length of their processes and in the number of their pencils. Since one cannot follow one fibre from beginning to end, it is impossible to define its actual length. In the human species the basket cells measure 11 to 20 micromillimetres, the molecular layer ·15 to ·14 mm., and the part of the layer containing the transverse fibres ·12 to ·22 mm.

Following on the description of these remarkable basket cells, their branches, and the fibre basket, the question naturally arises if they are really nerve elements, as Golgi and Ramón y Cajal believe them to be, or glia cells.[1] This is no easy matter to decide, as by Golgi's method both neuroglia and nerve cells are stained by silver. Kölliker inclines to the view of Golgi, and states the following as matter of fact:—firstly, all transitions exist between the basket cells and the small undoubted nerve cells of the molecular layer; secondly, the glia cells have, without exception, numerous branches passing off from all sides, mainly with sharp-angled divisions; and, thirdly, the basket cells are, like nerve cells, stained deep black, while glia cells have a red or yellowish-brown appearance. If the basket cells are really nerve cells, they exhibit structure of quite a peculiar nature, and the relation of branches of nerve cells to other such cells as exist here are nowhere else to be seen. This is surely no reason against this interpretation, since the recent examinations upon the construction of the retina and the brain show that we have to await much that is astonishing from further researches in this sphere.

4. *Purkinje's Cells.*

These are obtained readily in the human brain, and by Golgi's method present a picture of wonderful beauty. Their branches do not anastomose, and they pass out through the whole thickness of the molecular layer. Kölliker has not seen any connections between them and the pia mater or vessels, and only to a very small extent with the nerve processes of the small granular cells.

In relation to the position of Purkinje's cells, Henle first pointed out that their ramifications spread out in one single level, and were leaf-shaped, and that these leaves without exception lie in the cross plane of the convolutions. Deep tangential sections

[1] In this connection it is to be remembered that Gierke speaks of the "Neuroglia holes" of Purkinje's cells, "Die Stutzsubstanz des Centralen Nervensystems," II. Theil., in *Archiv für Mikr. Anat.*, Bd. xxvi. p. 188.

give good information upon the position of the bodies of the cells; these show that they are somewhat nearer together in the longitudinal than in the cross direction, and are not arranged in regular succession. Golgi has so well described the nerve processes of these cells, and Ramón y Cajal has confirmed it, that it is only necessary to add that Kölliker also saw the lateral branches which pass back into the molecular layer.

5. *The Nerve Fibres of the Granular and Molecular Layers.*

Of the three kinds of fibres which Ramón y Cajal describes as ramifying in the granular and molecular layers, Kölliker believes that the subsections (*a*) and (*b*) described above belong together, and correspond to the system of nerve-fibres which Golgi saw diffusing from the folia into the cortex. These varicose black fibres show inside the folia single acute-angled divisions, and so soon as they enter the granular layer they spread out into delicate rich ramifications, which pass through the granular layer and appear to end partly there and partly in the deeper portions of the molecular layer, *i.e.*, they end free, and are not further stained. In many preparations these endings show nothing special except slight varicosities, in others knotty or bushy swellings; it is probable that these conditions are artificial. As to Ramón y Cajal's third category, the so-called "Nidos Cerebellosos" which encircle Purkinje's cells, Kölliker only saw them in a single preparation from a young dog, and is disinclined to pronounce any opinion on them.

6. *The Medullated Fibres of the Cerebellum.*

For the investigation of these fibres, we possess most important means in the methods of Weigert and Pal.[1]

[1] Pal's modification has now almost entirely replaced the original method of Weigert. The process which I have found most serviceable is briefly as follows:—Blocks of tissue are hardened in Müller's fluid in an incubator at 35–40° C. for 10 days or a fortnight. Without washing off the bichromate solution, they are placed for 24 hours in 64 over-proof spirit, and kept in the dark. They are then prepared for imbedding in celloidin by placing them for 24 hours in absolute alcohol, and then in a mixture of absolute alcohol and ether, equal parts. From this they are transferred to a weak solution of celloidin, or to prevent waste chips of celloidin may be added to the alcohol and ether. When saturated, the blocks are imbedded in a strong solution of celloidin, which is then allowed to solidify. They are gummed, by means of strong celloidin, to pieces of cork, which are placed for 24 hours in a vessel containing methylated spirit. They are now ready for cutting. The sections having been thoroughly washed in distilled water are transferred to the following solution:—Hæmatoxylon, 1 gramme, absolute alcohol, 10 c.c., distilled water, 90 c.c., to which a few c.c. of saturated solution of lithium carbonate has been added. They remain in this for 24 hours in a warm place. They are then washed in distilled water, and transferred for 20–30 seconds to a solution of permanganate of potash ·25 gramme; water, 100 c.c. It is absolutely

At the borders and lateral parts of the convolutions, where the grey matter pushes against the white substance, single fibres and fibre bundles pass off from this in order to pass through the entire thickness of the rust-coloured layer, and to form in it a plexus, which takes up the granules in its meshes. In the deep parts of the furrows, different relations are found; here the white matter shows arching fibres, which, similar to those of the great brain, appear to act as commissural fibres of the convolutions, and only give off a few fibres to the rust layer. On examining this plexus more carefully, one finds that it contains a certain number of coarse fibres, which run straight towards the molecular layer, elements which undoubtedly are in great part continuations of the axis-cylinder process of Purkinje's cells. On the other hand, one cannot help thinking that the plexus of the rust layer consists entirely and alone of such fibres as Henle surmised. Still much more certain is it that it contains an excess of medullated fibres, which penetrate into the molecular layer. If one follows the plexus right up to Purkinje's cells, one finds that its elements pass under the cells into a layer of cross fibres, which, on cross section, consists of discrete bundles which are joined together by numerous fine bridges. Longitudinal sections complete the picture, and show the bundles as a not sharply-defined round collection of points. From these superficial cross bundles a quantity of oblique and straight ascending fine fibres develope, which, encircling Purkinje's cells and passing between them, enter the molecular layer, and in this strike into a longitudinal direction. In clean cross sections these elements appear as small points, which lie sometimes outside, sometimes between Purkinje's cells; and in longitudinal sections of the convolutions one finds a zone of fibrils running parallel to their surfaces. Besides these elements one finds a certain number of radial (straight and slightly oblique) ascending medullated fibrils in the molecular layer, of whose quantity it is not easy to make a calculation. They are, as a rule, few in pure cross sections, abundant on longitudinal sections of the convolutions. With reference to the diffusion of these medullated fibres throughout the molecular layer, recent examinations have given different results than previously were noted. There is no doubt that they are more numerous in the inner fourth or fifth parts of this layer, but they are also observed in the superficial strata, just under the pia mater.[1]

Can the following question be answered in the affirmative? "Do

essential that this solution be freshly prepared each time. Without washing off the permanganate transfer them to *Pal's fluid*: oxalic acid, ·5 gramme sulphite of potash, ·5 gramme, distilled water, 100 c.c. When differentiation has been complete, remove the sections and wash for several hours. They may now be stained in carmine or picrocarmine or mounted as they are in balsam.—W. A. TURNER.

[1] It seems probable that in Weigert preparations dark-stained glia fibres may be mistaken for very fine medullated nerve fibres. The former are of equal diameter and always serpentine; the latter are straight and usually slightly varicose.

the medullated fibres of the cerebellum possess branches?" It is extremely difficult to define such branches, except in the molecular layer. The reason of this difficulty is found in the fact that the medullated sheath is absent at the divisions, and therefore escapes staining. This has long been known to occur at the division places of peripheral nerve fibres. Ramón y Cajal and Flechsig think that this occurs in the central nervous system. The former has seen non-medullated portions in the medullated nerve processes of Purkinje's cells, while the latter has described non-medullated places in the already medullated nerve processes of the pyramidal cells of the cortex cerebri, where they divide and give off lateral branches. Kölliker has also seen such conditions in the fibres of the granular and molecular layers, but could not say whether they were natural or only imperfectly stained. In well-stained Weigert preparations from man and cats he saw such divisions in the molecular layer in only thirteen cases.

8. *The Neuroglia.*

In the white matter numerous large star-shaped cells are found, whose long-branched processes course between the nerve fibres, and apply themselves to the vessel walls. Similar cells are seen in the granular layer and at the border of the molecular layer, which send their long-branched processes right through this layer to its surface, to end at the inner aspect of the pia mater in a small club-shaped swelling.

We have now in conclusion to consider very briefly the connection of all these elements of the cerebellar cortex. This is no easy matter, and only a few hints are given in which to base further examinations: —1. Which of the fibres demonstrated by Golgi's method are medullated? Certainly the main stem of the nerve process of Purkinje's cells. Kölliker also believes that the longitudinal fibres of the molecular layer, which are the terminations of the nerve processes of the small granular cells, are medullated for a considerable distance. He looks upon these fibres as identical with the longitudinal fibres of the molecular layer described by Golgi. 2. How these longitudinal fibres end has been described under the section dealing with the small granular cells. 3. Considering still further the derivation of the medullated fibres of the cerebellar cortex, one may accept the facts that part of the fibres of the white folia end in the granular layer, part in the molecular layer. In the former they exist free and non-medullated, and lie partly between the granular cells and partly around the border of Purkinje's cells. In the latter they have associations with the nerve processes of the small multipolar nerve cells, which do not take part in the formation of the fibre basket.

The physiological value of the various elements above described is briefly summarised thus:—

All free and non-medullated processes of nerve fibres are undoubtedly *centripetal* elements; all medullated fibres arising from

cells are *centrifugal.* Branched protoplasmic processes of nerve cells probably conduct centripetally; the so-called nerve-processes of such also, when they are not medullated, conduct centrifugally. To this last appear to belong—1. The nerve-process of the large cells of the granular layer. 2. The nerve-process of the basket cells of the molecular layer.

Journal of Anatomy and Physiology.

THE RELATIONS OF THE DENTARY ARCADES IN THE CRANIA OF AUSTRALIAN ABORIGINES.[1]

By PROFESSOR SIR WM. TURNER, M.B., LL.D., D.C.L., F.R.S.

IT is well known that in the European skull the span of the upper dentary arcade is somewhat greater than that of the lower, so that the upper arch of teeth slightly overlaps the lower both laterally and anteriorly. The projection of the upper teeth beyond the lower is well marked in the region of the incisors and canines, so that when the jaws are clenched the lower teeth fit within those of the upper jaw, and the cutting edges and labial surface of the former are in contact with the lingual surface of the latter. Hence "tartar" does not accumulate on the lingual surface of the upper incisors, but is prevented from forming there by the friction of the lower incisor teeth.

There is no difficulty in satisfying oneself of the accuracy of this relation in the European skull. We may do it on our own persons, or on the skulls of the subjects received into the dissecting-rooms. But if we wish to examine the relations of the dentary arcades in the coloured races, we find that so many of the crania in our museums are either without the lower jaw, or, if the mandible be present, have so many teeth wanting that an accurate comparison is impossible.

In the collection of seventy-one crania of aboriginal Australians in the anthropological cabinet of the Anatomical Museum under my charge in the University of Edinburgh, only one specimen has all the teeth in place; but in a few others they are so nearly complete that the relations of the two arches can be

[1] Communicated to the Anatomical Society, May 25, 1891.

satisfactorily ascertained. By the study of these specimens I have recognised that in many Australian skulls an interesting modification exists in the relations of the upper and lower incisors and canines, as compared with the European skull.

The skull with the complete dentition (No. 1) was an adult male of the Narrinyeri tribe, inhabiting the country around Lake Albert, South Australia.[1] The cusps had been worn off the crowns of the molars and premolars, and the cutting edges

Right profile of Australian of Narrinyeri tribe. From a photograph by A. L. Turner, M.B.

of the incisors had been somewhat blunted. The width of the two dentary arcades in the molar region, taken by measuring between the outer surface of the crowns of the teeth, was as follows: at 1st upper molars 62 mm., at 1st lower 54 mm.; at 2nd upper 65 mm., at 2nd lower 62 mm.; at upper wisdom 64·5

[1] This skull was presented through my colleague, Sir Douglas Maclagan, by R. E. Minchin, Esq., of Adelaide.

mm., at lower wisdom 65·5 mm. When the condyles of the lower jaw were articulated and placed in contact with the ridge which bounded the back of the glenoid fossa, and the teeth were clenched, the lower canines and incisors did not fit within the upper arcade; but the two sets of teeth were in contact by their cutting edges, and formed a continuous curve from above downwards. In the incisor region, therefore, the lower dentary arch projected as far forward as the upper. In the molar region the crowns of the lower wisdoms did not extend quite so far back as those of the upper wisdoms, and from behind forwards the anterior surface of the crown of a lower tooth extended materially in front of the corresponding upper tooth, so that on the right side the lower canine was situated in front of the upper, and below the upper lateral incisor, whilst the two lower incisors were below the upper central incisor; on the left side, however, the lower canine and incisors were not so completely in front of their upper homologues.

With the view of determining the relative width of the upper and lower dentary arcades in the molar region, I measured all the Australian skulls in the collection in which the corresponding upper and lower molars were preserved. Including the skull above described, eighteen crania possessed the first pair of upper and lower molars, and in all the width at the crowns of the upper pair was greater than that at the lower. In two specimens the excess was 8 mm., in four 7 mm., in three 6 mm., in one 5 mm., in six 4 mm., and in two 3 mm.; the mean of the series was 5 mm. A similar number of specimens possessed the second pair of upper and lower molars, in all of which, with one exception, the width at the upper pair exceeded that at the lower. In one the excess was 8 mm., in one 7 mm., in one 6 mm., in four 5 mm., in two 4 mm., in six 3 mm., in two 2 mm., and in one they were equal. The mean of the series was 4 mm. In eleven specimens the upper and lower wisdom teeth were present; in seven of these the width was greater in the upper arch, whilst in four the lower arch was wider than the upper. It follows therefore from these measurements that the upper dentary arcade in the Australian skull is, with rare exceptions, appreciably wider than the lower in the region of the first and second molars; whilst at the wisdom teeth, though the upper

arch is more frequently wider than the lower, in a proportion of the specimens the lower possesses the greater width.

I may state that the maximum width at the crowns of the 1st upper molars was 66 mm., and in twelve specimens the width was 60 mm. or upwards, whilst the minimum width, in one specimen only, was 55 mm. The maximum width at the crowns of the 1st lower molars was 63 mm., and the minimum width was 51 mm. The maximum width at the crowns of the 2nd upper molars was 73 mm., and three specimens were 70 mm. or upwards, whilst the minimum width was in one specimen 57 mm. The maximum width at the crowns of the 2nd lower molars was 69 mm., and the minimum width was 57 mm. The maximum width at the crowns of the upper wisdoms was 75 mm., and the minimum was 55 mm. The maximum width at the crowns of the lower wisdoms was 72 mm., and the minimum was 62 mm.

I have also made a series of measurements of the width at the crowns of the molar teeth in European skulls. In all the specimens, with one exception, the transverse diameter at the 1st molars, in the upper dentary arcade, exceeded the lower, but in no instance was the excess more than 4 mm. The mean of the series was 2·5 mm. The transverse diameter at the 2nd molars, with two exceptions, was greater in the upper arcade than in the lower, but in no instance was the excess more than 5 mm., and the mean of the series was 2·4 mm. At the wisdom teeth the transverse diameter was sometimes greater at the upper pair, at others at the lower pair.

From this comparison it follows that both in European and Australian skulls the upper dentary arcade, with rare exceptions, is wider than the lower at the 1st and 2nd molars; but that in Europeans the excess of width is, as a rule, not so marked as in the Australians. In the region of the wisdoms, again, in both series, sometimes the upper, at others the lower, arcade may have the greater transverse diameter. But in the European skulls the absolute width at the molar crowns was less than in the Australians, and in both sets of measurements it should be stated that the men predominated over the women. The maximum width in the Europeans at the 1st upper molar was 63 mm., at

the 1st lower 60 mm.; at the 2nd upper 66 mm., at the 2nd lower 64 mm.; at the upper wisdom 68 mm., at the lower wisdom, in the same skull, 71 mm.

Anthropologists have long recognised that in the Australian crania the teeth are larger than in Europeans, especially in the molar series. Professor Flower, C.B., conducted a few years ago a research into the size of the teeth as a race character,[1] but for the reason stated in his paper, the investigation was confined to the upper molar and premolar teeth. He placed the Australians in the megadont group, whilst the Europeans were microdont. Owing to the limitations under which the research was conducted, no comparison, as regards size, between the upper and lower premolar and molar series is given. I have, to some extent, endeavoured to work this out in the crania at my disposal. In thirteen skulls I was able to measure the length of the crowns of the premolar and molar series in both jaws, either on both sides, or on only the right or left side. In all the specimens, with one exception, this series of teeth in the lower jaw was collectively of greater antero-posterior diameter than in the upper, in one specimen being as much as 5 mm., but the mean of the thirteen specimens was 3 mm. The actual length of the series in the different specimens ranged in the upper set from 41 to 51 mm., in the lower set from 44 to 56 mm.

In the same skulls I also took the antero-posterior diameter of the crowns of the three true molars inboth jaws. In one skull the right upper series was 1 mm. longer than the lower, but on the left side they were equal; in all the rest the lower set exceeded the upper, the maximum excess being 5 mm., and the mean 2·8 mm. The actual length of the true molar series ranged in the upper set of teeth from 29 to 36 mm., and in the lower set from 31 to 40 mm.

Owing to the lower set of premolars and molars exceeding the upper in antero-posterior diameter, the crowns of the corresponding teeth in the upper and lower jaws in the great majority of the specimens were not in the same vertical plane; the lower teeth almost invariably were situated partially in front of the upper, and in some cases as much as one-half of the

[1] *Journal Anthrop. Institute*, November 1884.

crown of a lower true molar was in front of the crown of its upper homologue, and the anterior lower bicuspid was in apposition with the upper canine. As regards the wisdom teeth, it should be said that whilst in many cases the back of the crown of the upper wisdom projected a little behind that of the lower, in others the relation was either reversed, or the backs of the upper and lower wisdoms were in the same vertical plane.

I have also examined a number of European crania as to the relative antero-posterior diameter of the upper and lower molar series. When both premolars and molars were taken together, the lower series invariably exceeded in length the upper, the greatest excess measured being 5 mm., and the mean being 3 mm. The actual length of the series in the skulls examined ranged from 37 to 45 mm. in the upper jaw, and from 40 to 46 in the lower jaw. Similarly the lower true molars exceeded the upper in their antero-posterior diameter. The greatest excess measured was 4 mm., and the mean of the series was 2·3 mm. The actual length of the true molars ranged from 26 to 31 mm. in the upper jaw, and from 27 to 34 mm. in the lower jaw. As regards the relative position of the upper and lower teeth, the crowns of the lower molars in some instances projected only slightly in front of their upper homologues, but in others a considerable proportion of the lower crown was in front of the corresponding upper tooth. Sometimes the upper wisdom projected a little behind the lower, in others the reverse was the case.

I may now pass to the consideration, in the Australian skull, of the relations of the dentary arcades in the incisive and canine region. In the specimen (No. 1) described at the beginning of this communication the upper arcade was seen not to overlap the lower anteriorly, but they were in apposition with each other by their cutting edges (see figure, p. 462). Notwithstanding the large number of Australian crania in the collection, only two specimens, in addition to No. 1 above referred to, had retained the whole of the incisor and canine teeth in their sockets; but in several others these teeth were only partially lost, so that one could form a conclusion how these teeth had been related to each other. In one of the two complete specimens (No. 2), an adult male from

Port Stephens, N.S.W.,[1] the apposition of the free edges of these teeth closely resembled the condition described in No. 1, but the lower canine was not so completely in front of the upper canine as in that specimen. In the other of the two complete specimens (No. 3), an adult male from Benalla, Victoria,[2] there was no overlapping of the lower incisors and canines by the upper, and the crowns of both sets of teeth had been much worn and flattened by mutual friction. In an adult male skull from Manly Cove, N.S.W.[3] (No. 4), in which the right upper central incisor had been artificially extracted at puberty and the socket absorbed, when the jaws were clenched, and the grinding surfaces of the upper and lower molars were in contact, the cutting edge of the lower incisors was separated by a slight interval from that of the upper, but the lower were not overlapped by the upper, though the anterior surface of the crowns of the lower incisors was almost in the same vertical plane as the back of the crowns of the upper incisors. In seven specimens in which several of the more anterior teeth were lost, but where a sufficient number remained to enable these relations to be determined, it was evident that the upper incisors and canines did not overlap the lower. From these observations I am satisfied that in a considerable proportion of the skulls of aboriginal Australians the relations of the teeth in the incisive region differs from the prevailing relation in Europeans.

But in a small proportion, four specimens of Australian crania, in which some of the incisors had been preserved, it seemed as if the lower teeth had not projected so far forward as the upper, and that therefore they were overlapped by the latter, as in Europeans.

The question now arises, Can we give a satisfactory explanation of the peculiarity exhibited by so large a proportion of Australian crania? If we look at the configuration of the incisive region of the upper jaw in the Australian skull we find that it is much more prognathic, and the roots of the incisor teeth slope more obliquely downwards and forwards

[1] I am indebted for this specimen to Mr Samuel Hyam, student of medicine.
[2] Presented by W. G. Howitt, Esq., Surgeon, Melbourne.
[3] Presented by Professor Anderson Stuart.

than in Europeans. On this ground, therefore, we might have expected to have found the upper teeth in Australians projecting to a greater extent in front of the lower incisors, than in Europeans; but this, as we have seen, is not the case. One should look, therefore, if, either in the development of the teeth, or in the form and growth of the lower jaw, or in the construction of the skull itself, anything has occurred to counteract the greater prognathism of the upper jaw, and to bring the crowns of the lower incisors into a continuous curve with the upper teeth. I have already referred to the greater magnitude of the teeth in Australians, and have given comparative measurements which show that the dentary arcades in this race are both wider and longer than in Europeans. But whilst the absolute length is different, it does not seem as if the relative length of the upper and lower arcades to each other was much affected. For although the mean antero-posterior diameter of the lower true molars was longer than that of the upper by 2·8 mm. in the Australians, and by only 2·3 mm. in the Europeans, yet, when the corresponding diameter of both the premolar and molar teeth was measured, the preponderance in length of the lower over the upper series was the same, viz., 3 mm. in both sets of skulls. Hence one cannot say that the lower incisors and canines are pushed further forwards by the growth of the molar-premolar teeth in the one set of skulls more than in the other. Neither does there seem to be sufficient difference in the direction of the lower incisors in the Australians, when the jaws are closed, to bring them immediately below, rather than behind, the upper incisors.

As regards the form of the lower jaw itself, there does not appear to be such a modification in its shape as would cause its body to be projected forward so as to bring the lower incisors into the same plane as the upper. When the angle of the lower jaw does not approach a right angle, but is obtuse as in old persons, the body of the bone is projected forward beyond the vertical plane of the upper jaw. But in the Australian skulls, which possess the character that I am describing, the angle of the lower jaw is even more pronouncedly rectangular than in the majority of adult European male crania. Moreover, the chin is not as a rule so prominent as in well-formed European skulls.

I have come, therefore, to the conclusion that the want of overlapping of the lower jaw by the upper in the incisor region is not due to a forward growth of the mandible, or its contained teeth, to an extent proportionately greater than that of the upper jaw, but that some other explanation is to be looked for.

If we examine the skulls of Mammalia which possess upper and lower incisors, we find that, as a rule, the cutting edges are in contact with each other when the jaws are closed. I may cite in illustration the Horse, the Carnivora, and Pinnipedia. In the Quadrumana also a similar character is seen. Anyone who examines the skulls of the Gorilla, Chimpanzee, and Orang, as well as those of tailled Apes, will see, if the teeth have not been lost, that the lower canine lies nearer the mesial plane than the upper, and that the incisors are in apposition by their cutting edges, which in old skulls are flattened from use. Associated with this relation of the incisor teeth is a prognathic condition of the upper jaw, much exceeding what is seen in any human skull.

The apposition of the upper and lower incisors in so many mammals seems therefore to be due to something more than a local cause affecting the jaws only. It is in all probability occasioned by a modification in the construction of the skull itself, which affects the relation of the face to the cranium proper.

Professor Cleland, in an important Memoir "On the Variations of the Human Skull,"[1] directs attention to the smallness of the cranial curvature and the length of the base, as compared with that of the arch in the Chimpanzee and Orang when compared with the human skull, and he concludes his chapter on this subject as follows:—

"The advance in form of the human brain, as compared with the brains of the higher Apes, consists partly in an increase of cerebral curvature, dependent on depression of the sphenoid and ethmoid, and on descent of the orbital roofs towards the level of the ethmoid, but to a greater degree consists in increased expansion, both in height and breadth, of the cranial dilatation of the cerebro-spinal canal."

In a preceding chapter he had called attention to the fact

[1] *Trans. Roy. Soc. Lond.*, 1869.

that, in uncivilised people, while the length of the arch is very variable, the length of the base line is always great. He gives the proportion of the arch to the base in the skulls of two Australians as 2·63 to 1, whilst the mean of nine Irish skulls is 2·89 to 1, and that of eight Germans is 2·80 to 1.

The Australian skulls measured by Cleland were too few to give the mean of the race, so that it was obviously advisable to make some additional observations on this matter.

In the tables of measurements which I have published in the "Challenger" *Reports*[1] I have recorded the longitudinal arc of the cranium, the antero-posterior diameter of the foramen magnum and the basi-nasal diameter (basion to narion) in a number of crania. Twenty male adult Australians were measured, and assuming the length of the foramen magnum + the basi-nasal diameter to give the base line, then the arch is to the base line as 2·72 to 1. The maximum base line was 150 mm. in two specimens; the minimum 128 mm.; whilst the mean of the series was 139·8 mm. The maximum longitudinal arch was 410 mm., the minimum 364 mm., and the mean of the series 380·4 mm. The great projection of the glabella in so many Australian crania would of course add materially to the length of this arch. The Narrinyeri skull (No. 1), which is not included in the tables of measurements, had a base line 132 mm. in length and an arch 358 mm., the proportion being 2·7 to 1, which is a fraction below the mean of the twenty crania.

I have obtained similar measurements from a series of seventeen adult male crania of Lowland Scots obtained from known localities. In them the arch was to the base line as 2·80 to 1. In these skulls the maximum base line in one specimen was 140 mm.; the minimum was 127 mm.; whilst the mean of the series was 134·3. The maximum longitudinal arch was 397 mm., the minimum 361 mm., and the mean of the series was 376·5. The skulls of the Lowland Scots, notwithstanding their much greater capacity, had, as a rule, a shorter glabello-occipital diameter, for whilst the mean length of the seventeen Lowlanders was 185·7, that of the twenty Australians was 191·3.

These measurements, obtained from a larger series of specimens, support the statement made by Professor Cleland that the

[1] "Zoology," Part xxix., 1884.

base line in the skulls of uncivilised people is long, whilst the proportion of arch to base line is less in the Australians than in Europeans.

It is difficult in the male Gorilla, on account of the size of the occipital and sagittal crests, to determine in a skull which is not longitudinally bisected the arch of the cranial vault; but there is no difficulty in taking the base line by the same method as in the human skulls above referred to. From a series of measurements of five adult male Gorilla skulls in the University museum, in which the tape included the occipital but not the sagittal crest, the proportion of arch to base line was as 1·9 to 1; in a young Gorilla in which the crests were not developed it was 1·6 to 1. In the crania of two Orangs, in which the basi-cranial synchondrosis was not closed[1] the mean proportion of arch to base line was 1·6 to 1; whilst in the skulls of two adult Chimpanzees the mean was 1·7 to 1. It is obvious, therefore, that in the Anthropoid apes the base line is very long as compared with the longitudinal arch of the cranial vault. The absolute length of the base line was much greater in the adult male Gorilla than in the human crania, the mean in the five skulls being 163·8 mm., and even in the much smaller skull of the young Gorilla it was 129 mm. The mean base line of the two young Orangs was 119·5 mm. and of the two adult Chimpanzees 123 mm.

The longer base line, when occurring along with an arch of shorter dimensions, is associated with a modification in the cranio-facial curvature; it affects the relation of the face to the cranium, and influences, I believe, the position of the upper jaw. With the shortening of the base line, the more horizontal direction of the ethmoido-cribriform plate, and the greater development of the curve of the cranial vault, especially in the frontal region, the upper part of the face lies more immediately below the forehead, the longitudinal axis of the superior maxillæ approaches in direction to the vertical, the prognathic character of the upper jaw is diminished, the lower jaw slightly recedes, and the lower dentary arcade becomes included so far within the upper that the upper incisors overlap the lower.

[1] In one of these skulls all the permanent teeth had erupted; in the other, all, except the wisdoms, were in place.

In conclusion, I would say that the relation of the upper to the lower incisor teeth which I have found to prevail so frequently in the aboriginal Australians is also occasionally seen in the skulls of other races. Thus in the University collection a similar arrangement exists in a Bushman, a Malay, and an Esquimaux, but the number of specimens of these races with perfect sets of teeth is at present too small to enable me to draw a general conclusion from them.

DOUBLE RIGHT PARIETAL BONE IN AN AUSTRALIAN SKULL. By Professor Sir WILLIAM TURNER.

THE Australian skull (No. 1), the character of the teeth of which I have described in the preceding communication, possesses, as may be seen from the figure on page 462, a very interesting peculiarity in the right parietal region.

The right parietal bone is divided into an upper and a lower part by a distinct antero-posterior suture, which commences behind at the lambdoidal suture 49 mm. below the hinder end of the sagittal suture, and terminates in front by joining the coronal suture 55 mm. below the anterior end of the sagittal suture. The upper division of the bone is 110 mm. long by 74 mm. in its greatest vertical diameter; the lower division is 103 mm. long by 61 mm. in greatest breadth; hence the division is into two unequal portions. The intraparietal suture is highly denticulated in the greater part of its extent, but is simple at its anterior and posterior ends. The curved temporal ridge runs from before backwards immediately below the suture, and does not mark the upper division of the bone. Hence the temporal fossa is less in its vertical diameter than one usually sees in the male Australian skull. A parietal eminence could not be distinctly differentiated on the right side.

On the left side the parietal bone was normal, and a small sutural bone was situated at the asterion.

Some years ago I described and figured an adult male skull obtained in the Admiralty Islands by the "Challenger" Expedition,[1] in which a somewhat similar division of the right parietal into an upper and a lower division was present, but both the intraparietal and lambdoidal sutures were complicated with sutural bones. In my published account of this skull I briefly referred to the cases of similar, or almost similar, variation in ossification which had been previously described in fœtuses by

[1] "Zoology," *Challenger Expedition*, Part xxix., plate iv., p. 57, 1884.

Van Doeveren, Wenzel Gruber, Traquair and Hyrtl, and in adults by Winslow, Von Sömmerring, Wenzel Gruber, Lucæ, Welcker and Hyrtl.

It is clear that in all these specimens the double parietal bone must have arisen from two distinct centres of ossification. In this connection I may refer to the observations of Toldt (quoted by Professor Thane),[1] who saw in the normal ossification of the skull in the parietal area two distinct nuclei, an upper and a lower, by the fusion of which the parietal eminence was produced. In these abnormal specimens the two centres of ossification had not undergone fusion, a proper parietal eminence was not produced, and the two areas of ossification remained distinct and separated from each other by an intraparietal suture.

[1] *Quain's Anatomy*, 1890.

CONTRIBUTIONS TO THE PHYSIOLOGY AND PATHOLOGY OF THE BLOOD. By ROBERT MUIR, M.A., M.D. (EDIN.), *Assistant to the Professor of Pathology, Edinburgh University.* PART III.

(*Continued from* page 378.)

CHLOROSIS AND ALLIED CONDITIONS.

I HAVE included in this class, in addition to cases of ordinary chlorosis, some others of less definite nature, the chief alteration in the blood being irregularity in the shape of the red corpuscles, with very slight diminution in their number. In all instances the patients were females.

Summary of Alterations found in Chlorosis.—Variations in the size of the red corpuscles are always more numerous than usual, the smaller forms being specially abundant. Megalocytes also may be found, but they are much less numerous than in pernicious anæmia. Irregularities of shape appear very frequently. They were present in all my cases and were sometimes very numerous. The poikilocytosis does not always vary in degree with the diminution of the number of the red corpuscles, being sometimes very well marked when the number is very little reduced. Gram[1] also found that the average size of the corpuscles in chlorosis was diminished, and that poikilocytes were very common. In none of these cases did I see any nucleated red corpuscles.

The leucocytes are generally diminished in number, sometimes markedly so; and even more striking is the diminution in the proportion of the multinucleated forms. In about 50 per cent. of my cases the number of the uninucleated exceeded that of the multinucleated. This condition of the leucocytes closely resembles that found in many cases of pernicious anæmia.

The number of blood-plates is generally considerably increased, though not in proportion to the degree of the anæmia. In one case (No. 34) they were little increased when the anæmia

[1] Gram, "Ueber die Grosse der rothen Blutkörperchen," *Fortschr. d. Med.*, 1884.

Table III.—*Chlorosis and Allied Conditions.*

	Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.[1]	Poikilocytes.	Nucleated Red Corpuscles.
Case 22—C. M'L., 31, F. Anæmia with gastric symptoms.	Dec. 4.	4,160,000	6,000	356,000	1:1·1	Numerous.	None.
	„ 17.	4,075,000	7,000	287,500	1:1·3	„	„
	„ 29.	4,380,000	8,000	208,000	...	Less numerous.	„
Case 23—J. M., 25, F. Chlorosis.	Nov. 14.	3,810,000	...	...	1:1·2	Numerous.	None.
	„ 24.	4,480,000	4,500	...	...	„	„
	Dec. 5.	4,400,000	5,000	326,000	1:1·7	„	„
	„ 17.	4,341,000	8,000	232,000	...	„	„
Case 24—J. M., 46, F.	Nov. 8.	4,146,000	9,000	280,000	1:2·4	Numerous.	None.
Case 25—G. W., 29, F. Chlorosis.	Jan. 31.	4,233,000	7,000	598,000	...	Numerous.	None.
	Feb. 9.	4,600,000	7,000	372,000	1: ·89	„	„
	„ 20.	4,501,000	5,500	358,000	1: ·83	„	„
	Mar. 3.	4,440,000	4,000	422,000	1: ·63	„	„
	„ 13.	4,555,000	3,500	368,000	1: ·6	„	„
Case 26—J. C., 25, F. Chlorosis.	Mar. 1.	3,537,000	3,500	470,000	1: ·66	Numerous.	None.
	„ 8.	3,970,000	5,000	476,000	1: ·7	„	„
	„ 13.	4,070,000	2,500	416,000	1: ·74	„	„
Case 27—M. C., 25, F. Chlorosis.	Jan. 26.	2,967,000	4,000	328,000	1: ·75	Few.	None.
	„ 31.	3,200,000	4,000	352,000	...	„	„
Case 28—M. T., 20, F. Chlorosis.	Mar. 22.	2,547,000	2,000	412,000	1: ·8	Few.	None.
	„ 29.	3,013,000	2,000	453,000	1: ·1	...	„
Case 29—J. C., 18, F. Chlorosis.	Mar. 26.	2,641,000	5,000	304,000	1: ·72	Numerous.	None.
	„ 31.	2,827,000	3,500	324,000	1: ·77	„	„
Case 30—C. M., 16, F. Chlorosis.	Feb. 3.	3,647,000	3,500	396,000	...	A few.	None.
	„ 12.	3,900,000	3,500	439,000	1: ·9	„	„
Case 31—J. C., 21, F. Chlorosis.	Feb. 27.	3,520,000	4,500	410,000	1:1·1	Very few.	None.
Case 32—M. Y., 21, F. Chlorosis.	Dec. 23.	2,188,000	4,000	244,000	...	Numerous.	None.
Case 33—J. K., 16, F. Chlorosis and Dyspepsia.	Mar. 11.	3,354,000	6,500	407,000	1:1·3	Fairly numerous.	None.
	„ 22.	3,955,000	2,000	304,000	1:1·3	Few.	„
Case 34—J. G., 17, F. Chlorosis.	Mar. 8.	2,470,000	6,500	254,000	1:1·3	Numerous.	None.
	„ 15.	3,020,000	6,000	332,000	1:1·2	„	„
	„ 22.	3,510,000	5,500	464,000	1:1·4	Few.	„
	„ 27.	4,041,000	5,500	452,000	1:1 4	„	„
Case 35—H. T., 23, F. Post-partum Anæmia.	Jan. 15.	3,636,000	10,000	367,200	1:1·6	Numerous.	None.
	„ 24.	3,841,000	7,000	408,000	1:2	Few.	„
	Feb. 7.	4,620,000	9,000	324,000	1:2·3	Very few.	„

[1] This column shows the proportion of uninucleated to multinucleated leucocytes.

was greatest, but increased greatly during the process of recovery. I cannot, however, state this to be the rule in such cases. The size of the blood-plates is sometimes larger than usual, some being 3·5–4 μ, but this is not always so.

In all cases in which the hæmoglobin was estimated, the amount per corpuscle was decreased, and in some cases, where the number of red corpuscles was little altered, this decrease was considerable, and associated with marked poikilocytosis.

SECONDARY ANÆMIA.

Under this term are included all cases in which the diminution in the number of the red corpuscles is caused by, or secondary to, organic disease of various kinds—cancer, phthisis, &c. To illustrate the changes found, I have chiefly selected cases of cancer.

The degree of anæmia varies very much in these cases, the number of red corpuscles in some falling nearly to a million per c.mm. The changes in the blood are of the same nature in the various cases, differing only in degree. The reduction in the number of the red corpuscles is associated with variations in their size; 3 μ and 9 μ may be given as extremes, many are 6–7·5 μ. Megalocytes are found, but are comparatively rare. Poikilocytes may be present, and are sometimes very numerous. The number of corpuscles may be greatly reduced without any being present (*e.g.*, 1,332,500 in Case 37), while, on the other hand, they may be found when the number is about 2,500,000. I believe that they very rarely appear in secondary anæmia till the number has fallen below 3,000,000, and in this respect there is a contrast to the condition in chlorosis. The poikilocytes are generally of smaller size than in pernicious anæmia. Deterioration of the corpuscles is also seen in their paleness, greater softness and viscosity, and sometimes in a tendency to early crenation. In an advanced case of secondary anæmia the red corpuscles are generally pale and somewhat delicate-looking, and many small forms and poikilocytes are present. In only one case (Case 36) did I see nucleated red corpuscles, but there was hæmorrhage as a complication—an obscure case, but probably one of malignant disease in the alimentary canal.

TABLE IV.—*Secondary Anæmia.*

	Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.	Poikilocytes.	Nucleated Red Corpuscles.
Case 36— J. P., aged 50, Male. Abdominal Cancer (?).	Aug. 10.	1,048,000	23,000	346,000	1:4·3	Few.	A few.
Case 37— J H., 52. Pyloric Cancer.	Feb. 21.	1,332,500	8,500	408,000	1:3·3	None.	None.
Case 38— A. M., 55, F. Cancer of Stomach.	Feb. 29. Mar. 3. " 14.	1,775,000 1,765,000 1,680,000	7,500 6,000 8,000	338,000 322,000 282,000	1:3·5 1:3·5 1:4·1	Numerous. " "	None. " "
Case 39— J. G. Cancer of Stomach.	Jan. 23. Feb. 20.	2,610,000 1,960,000	18,000 13,000	528,000 550,000	1:5 1:5·2	Numerous. "	None. "
Case 40— A. H., 35, F. Cancer of Stomach.	Mar. 12. " 22.	2,775,000 2,514,000	12,000 10,500	442,000 448,000	1:3·3 1:3·1	A few. Numerous.	None. "
Case 41— A. M'K., 49. Cancer of Liver.	Feb. 4. " 13. " 18.	3,301,000 3,158,000 3,040,000	21,000 17,000 15,000	416,000 341,000 385,000	1:3·5 1:3·7 1:4	None. " Very few.	None. " "
Case 42— J. C., 62, F. Malignant Disease (?).	Dec. 6.	3,245,000	9,000	312,000	1:3	A few.	None.
Case 43— J. B., 45, F. Cancer of Liver.	Mar. 21. " 28.	3,525,000 2,853,000	10,000 9,500	322,000 426,000	1:4 1:3·9	None. "	None. "
Case 44— R. W., 50, M. Cancer of Stomach.	Feb. 28.	4,170,000	7,000	212,000	1:3·1	None.	None.
Case 45— J. D., 50, M. Lead Poisoning.	Feb. 1. " 7.	2,511,000 2,560,000	15,000 15,000	290,000 254,000	1:3·6 1:3·6	None. "	None. "
Case 46— J. T., 51, M. Lead Poisoning.	Feb. 5.	3,341,000	19,000	267,000	1:4·1	None.	None.

The leucocytes are often considerably increased in number, sometimes unaltered. A leucocytosis associated with cancer, &c., has been noticed by Hayem and others. If a leucocytosis be present, the increase is mainly on the part of the multinucleated leucocytes, so that their proportion to the other forms

becomes increased; and in some cases, where there is no leucocytosis, this alteration in the proportion is found.

The blood-plates are increased in number, generally to a considerable extent. Regarding this fact practically all observers are agreed.

TABLE V.—*Miscellaneous (Anæmia).*

	Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.	Poikilocytes.	Nucleated Red Corpuscles.
Case 47— J. F., 45, M. Malarial Anæmia.	Feb. 7.	1,165,000	5,500	125,000	1:2·5	Very few.	None.
	,, 14.	1,213,000	7,500	123,000	1:1·8	,,	,,
	,, 21.	1,223,000	6,000	127,000	1:1·5	None.	,,
	,, 28.	2,135,000	7,000	224,000	1:2	,,	,,
	Mar. 7.	2,215,000	8,500	159,000	1:1·9	,,	,,
	,, 19.	2,825,000	10,000	348,000	1:2·1	,,	,,
Case 48— J. G., 27, M. Malarial Anæmia (?).	Jan. 10.	3,585,000	11,000	332,000	1:3	Few.	None.
	,, 23.	3,636,000	11,000	312,000	1:2·7	,,	,,
Case 49— A. F., 46, M. Aortic Disease.	Mar. 7.	3,325,000	5,500	288,000	1:2·5	None.	None.
Case 50— A. B., 60, M. Aortic Disease.	Mar. 7.	4,218,000	8,000	316,000	1:1·6	None.	None.
Case 51— A. H., 39, M. Anæmia of doubtful nature.	Jan. 8.	1,765,000	7,500	152,000	1:1	Fairly numerous.	None.
	,, 14.	1,735,000	7,000	226,000	1:1·4	,,	,,
	,, 25.	1,976,000	7,000	201,000	...	,,	,,
	Feb. 8.	1,931,000	5,000	242,000	...	,,	,,

In the only well-marked case of malarial anæmia (Case 47) which I have had an opportunity of examining, there were no true poikilocytes present, but the red corpuscles showed a remarkable tendency to become folded, and form curious shapes after the blood was shed. A considerable number of the leucocytes contained coarse granules, which stained deeply with methyl-blue, as noted also in some cases of leucocythæmia (*v.* Pl. IX. fig. 3). The blood-plates were at first diminished in number, but afterwards somewhat increased. (Osler[1] also found that in such cases the blood-plates were few in number.)

In the cases of aortic disease there was little change beyond the diminution of the red corpuscles, and a slight increase of the blood-plates. The last case in this table was an obscure one, in which there was enlargement of the liver and spleen, and the changes are sufficiently indicated by the figures given.

[1] Osler, "The Hæmatazoa of Malaria," *Brit. Med. Jour.*, 1887.

Leucocythæmia.

Table VI.—*Leucocythæmia.*

	Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.	Poikilocytes.	Nucleated Red Corpuscles.
Case 52— M. R., 35, F. Leucocythæmia.	Dec. 12.	3,190,000	161,000	1,116,000	1:1·2 (v. text)	Few.	None.
	" 30.	3,280,000	152,000	1,210,000	...	"	"
	Jan. 20.	2,775,000	187,000	...	...	"	Very few.
[1] Case 53— G. R., 10, M. Leucocythæmia.	Dec. 30.	2,[illegible]00	[illegible]00	194,000	...	Very few.	None.
	Jan. 3.	2,[illegible]00	11[illegible]00	262,000	...	"	"
	" 7.	2,[illegible]00	2[illegible]00	230,000	...	"	"
	" 12.	2,[illegible]00	24[illegible]00	224,000	...	"	"
	" 14.	2,[illegible]00	2[illegible]00	223,000	...	"	"
	" 17.	2,[illegible]00	2[illegible]00	192,000	...	"	"
	" 23.	2,[illegible]00	21[illegible]00	...	...	"	"
	" 27.	1,[illegible]00	24[illegible]00	72,000	...	Few.	"
	" 30.	1,[illegible]00	2[illegible]00	19,000	...	"	"
	Feb. 3.	1,[illegible]00	2[illegible]00	7,000	...	"	"
	" 6.	1,[illegible]00	34[illegible]00	19,000	...	"	"
	" 9.	[illegible]00	[illegible]00	13,000	...	"	Very few.
	" 12.	[illegible]60	2[illegible]00	7,000	...	"	"
Case 54— A. H., 22, F. Leucocythæmia.	July 5.	947,500	687,500	31,000	...	Numerous.	Numerous.

In the second of these cases there was general enlargement of the lymphatic glands; in the third the mediastinal glands formed a large mass; whilst in the first the glands were unaffected. In all cases the spleen was enormously enlarged. In the second and third cases the bone-marrow, on *post-mortem* examination, showed an increased number of small round cells similar to those in the blood, but did not present the characteristic naked-eye characters which are found when the marrow is specially involved.

Summary of Changes in the Blood.—The red corpuscles present the alterations which are found associated with severe anæmia. They vary in size in some cases, measuring 4–9 μ, and poikilocytes may be present, especially if the anæmia is great. Megalocytes, as a rule, are not numerous. Nucleated red corpuscles are often present. They were present in all three cases, and were in considerable numbers in Case 54. They are usually of the typical structure, with a single spherical nucleus; but occasionally the nucleus is somewhat broken up, and there may even be two distinct round nuclei present, which are generally of unequal size (*v.* Pl. IX. fig. 10).

The leucocytes, in addition to the great increase in number,

[1] Reported by Dr J. Thomson and the present writer in *Internat. Jour. Med. Sci.*, April 1891.

show interesting alterations. Large corpuscles, up to 15 μ in diameter, which are not normally present, may appear in the blood. These have generally one large oval nucleus, which, however, may be indented at the side; more rarely there are two nuclei. The nucleus is large and poor in chromatin, whilst the protoplasm is finely granular, and stains almost as darkly as the nucleus (*v.* Pl. IX. fig 3). In Case 52 these large corpuscles formed nearly a fifth of the leucocytes present. They were associated with an increased number of ordinary multinucleated leucocytes and with numerous corpuscles containing coarse granules, which stained very deeply with methyl-blue. In this case the small uninucleated corpuscles were not increased in number. In the other two cases nearly all the corpuscles were of the small uninucleated variety, though larger uninucleated corpuscles were also present (*v.* Pl. IX. fig. 4). Multinucleated forms were very few, being absolutely as well as relatively diminished in number in Case 54. I have found from recent observations on other cases that these are the two common types of leucocythæmia, so far as the changes in the blood are concerned.

The condition of the blood-plates varies greatly in leucocythæmia, as is shown by the table. These and other cases show that when the uninucleated corpuscles alone are increased in number the blood-plates become very few, and in some cases may be almost absent before death. In the other type described they are generally increased in number, sometimes to a great extent, as in Case 52, which shows the largest number I have ever met with. Accordingly we find varying statements regarding the condition of the blood-plates in this disease by Riess,[1] Osler,[2] Halla,[3] Afanassiew,[4] &c.

LYMPHADENOMA.

In cases with enlargement of lymphatic glands, the diagnosis is generally difficult, and accordingly some of the following cases were possibly not cases of lymphadenoma. In others the features of the disease were well marked.

[1] Riess, *Archiv f. Anat. u. Phys.*, 1872, p. 257.
[2] Osler, "The Cartwright Lectures," 1886.
[3] Halla, *Fortschr. d. Med.*, 1883, p. 479.
[4] Afanassiew, *Deutsches Archiv f. Klin. Med.*, 1884, p. 217.

TABLE VII.—*Lymphadenoma, &c.*

	Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.	Poikilocytes.	Nucleated Red Corpuscles.
Case 55— J. K., 11, M. Lymphadenoma.	Nov. 6.	4,130,000	20,000	501,000	1:1·2	None.	None.
	„ 15.	4,180,000	15,000	...	1:1·1	„	...
	„ 23.	4,320,000	...	480,000	1:1·4	„	...
	Jan. 9.	4,200,000	15,000	402,000	1:1·1	„	...
Case 56— J. Y., 9, M. Lymphadenoma.	Mar. 13.	4,127,000	23,000	502,000	1:1·3	Very few.	None.
	„ 16.	4,117,000	19,000	456,000	1:1·5	„	...
	„ 22.	4,190,000	13,000	490,000	1:1·2	„	...
	„ 30.	4,256,000	19,000	452,000	1:1·6	„	...
Case 57— J. D., 49, M. Lymphadenoma.	Jan. 12.	4,276,000	22,800	512,000	1:2·1	None.	None.
	„ 23.	3,954,000	25,500	504,000	1:2·5	„	...
	„ 31.	3,950,000	21,700	518,000	1:2·4	„	...
	Feb. 7.	3,801,000	21,000	458,000	1:3·8	Very few.	...
Case 58— J. G., 21, M. Lymphadenoma.	Jan. 17.	4,560,000	35,000	488,000	1:2·6	None.	None.
	Mar. 19.	4,209,000	26,000	392,000	1:1·9	„	...
Case 59— J. D., 19, F. Lymphadenoma (?).	Feb. 2.	4,250,000	6,000	252,000	1: ·9	None.	None.
	„ 13.	4,280,000	6,500	268,000	1:1·1	...	...
Case 60— A. T., 21, F. Lymphadenoma (?).	Mar. 19.	4,181,000	10,500	308,000	...	None.	None.
Case 61— J. S., 29, M. Enlarged Glands Syphilitic (?).	Dec. 9.	4,740,000	7,000	272,000	1:1·5	None.	None.

When the red corpuscles become diminished in number, the usual changes—variations in size and irregularities in shape—are found. I did not find nucleated red corpuscles in any case, but in none was the anæmia very intense. The leucocytes were increased in number in four cases, their number in these being generally about twice the normal. In two of these the uninucleated leucocytes were chiefly increased, so that the proportion of multinucleated leucocytes was diminished; in other two all varieties were increased together. In the other cases the number of leucocytes was not increased, though in two the enlargement of glands was very great and widespread. These cases would show that the condition of the blood is not uniform, and I am not yet able to say exactly under what conditions the leucocytes are

increased, and what the increase signifies. In the number and character of the leucocytes, the blood in this disease differs from that found in leucocythæmia.

With regard to the blood-plates, it is noticeable that in all four cases in which the leucocytes were increased, they also showed a considerable increase in number, whilst in the other cases their number was nearly normal.

TABLE VIII.—*Cases with High Temperature.*

	Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.	Poikilocytes.	Temperature.
Case 62— W. G., [illegible] Suppur[illegible] Liver (?).	,, [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	,,	[illegible]
	,, 12.	3,[illegible]00	29,000	502,000	1:7·6	,,	Gradually fell, but irregular. On Feb. 22, 99·2°.
	,, 14.	3,[illegible]00	25,000	356,000	1:9	,,	
	,, 16.	2,[illegible]00	25,000	411,000	1:6·5	,,	
	,, 22.	2,[illegible]00	18,000	418,200	1:6·3	,,	Normal.
	Mar. 1.	2,[illegible]00	21,000	528,000	1:6	Very few	Normal to 101·6°.
	,, 6.	3,[illegible]00	17,000	494,000	1:5	,,	
	,, 19.	2,[illegible]00	10,000	448,000	1:5	,,	Slightly above normal.
	Apr. 1.	2,[illegible]00	14,000	416,000	1:8·9	,,	
Case 63— G. R., 5, M. Broncho-pneumonia and Nephritis.	Jan. 15.	3,[illegible]00	31,000	264,000	1:6	None.	100°–103. Jan. 18, fell at midnight.
	,, 16.	3,[illegible]00	49,000	422,000	...	,,	
	,, 17.	3,[illegible]00	36,000	542,000	...	,,	
	,, 18.	3,[illegible]00	47,000	463,000	1:4·6	,,	
	,, 19.	3,[illegible]00	27,000	428,000	...	,,	Normal or sub-normal.
	,, 21.	3,[illegible]00	17,000	...	...	,,	
	,, 23.	4,[illegible]00	10,000	418,000	...	,,	
	,, 24.	3,[illegible]00	9,000	411,000	1:2	,,	
	,, 26.	3,[illegible]00	10,000	362,000	...	,,	
	Mar. 1.	3,[illegible]00	8,000	166,000	1:1·5	,,	
	,, 10.	4,[illegible]00	6,800	311,000	1:1·2	,,	
	,, 19.	4,[illegible]00	6,000	242,000	1:1·9	,,	
Case 64— J. T., 50, F. Parotid Abscess.	Feb. 18.	3,491,000	25,500	488,000	1:7·8	None.	Irregular, rising to 103·4°.
	,, 21	3,519,000	16,500	424,000	1:5·9	,,	
	,, 25.	3,460,000	19,500	308,000	1:6·5	,,	
	Mar. 4.	3,327,000	28,000	321,000	1:6·1	,,	
Case 65— J. G., 17, M. Croupous Pneumonia.	Mar. 8.	4,254,000	20,500	96,000	1:3·9	None.	104°–105°.
	,, 9.	4,072,000	13,000	130,000	1:4·9	,,	
Case 66— T. M., 20, M. Acute Rheumatism.	Mar. 5.	4,909,000	12,000	142,000	1:3·8	None.	About 102°.

I have selected these cases as affording examples of changes which may occur when there is fever.

The first case (No. 62) is one of severe biliary colic and jaundice, with high temperature, lasting for some time and leading to a considerable degree of anæmia. During the time of observation the blood passed from nearly a normal condition to such as is found associated with a considerable degree of cachexia, the number of the red corpuscles decreasing by nearly two millions, and the usual alterations

in size, &c., occurring. During the time of high temperature the leucocytes were increased in number, the proportion of multinucleated forms being markedly increased at the same time, so that at one time they numbered 90 per cent. of all the corpuscles. The blood-plates, though normal at first, increased greatly in number.

The second case is noteworthy for the very rapid fall in the number of leucocytes which took place—from 47,000 to 10,000 in the course of five days. It is also noteworthy that the proportion of multinucleated leucocytes, which was at first greatly increased, also fell to normal at the same time. The number of blood-plates fell a little later than the leucocytes.

The third case, as regards the condition of the blood, closely resembles the first, the high proportion of multinucleated leucocytes being again specially marked.

These cases prove conclusively that the number of blood-plates may be greatly increased during fever, and that the increase is not found only after defervescence, as Hayem[1] and Fusari[2] believe. This agrees with what Halla describes in such conditions. In cases of erysipelas, &c., he found the blood-plates forming very large heaps between the red corpuscles, and often occupying a large proportion of the field. In the last two cases the number of the blood-plates was rather less than normal, and the changes in the leucocytes were less marked than in the others.

I shall briefly summarise the changes found in a variety of other conditions. In cases of suppuration—psoas abscess, empyema, abscesses in lung, &c.—the leucocytes were increased in number, the highest number reached being 42,000. The proportion of multinucleated leucocytes was also increased, "Prop. A" being generally about 1 : 6 ; in one case, 1 : 13·5. The red corpuscles were generally slightly diminished in number, and were sometimes softer and more viscous than usual. The blood-plates also were, as a rule, increased in number. In many cases of wasting disease, with little anæmia—phthisis, tubercular peritonitis, chronic gastric disease, &c.—the number of blood-plates was distinctly increased, whilst the leucocytes were less affected. In a case of cancrum oris there was marked increase of leucocytes, especially of the multinucleated variety; number of leucocytes = 28,000 ; Prop. A = 1 : 7·5. The blood-plates also were increased. A similar condition of the leucocytes was seen in a case of malignant jaundice, in which, however, the most striking feature was the character of the red corpuscles. They were of remarkably soft consistence and ran together in string-like masses, so that a few minutes after the blood was shed their outlines were not

[1] Hayem, *Du Sang*, pp. 471, 904.

[2] Fusari, quoted by Eberth and Schimmelbusch, *Die Thrombose*, p. 33.

recognisable. The blood-plates were slightly decreased. I have already described the changes which take place in many cases of cancer, but I ought to add that in a case of œsophageal cancer with stricture, associated with profound emaciation, there was practically no anæmia, and no change in any of the elements in the blood. This agrees with what has been observed in some cases of starvation. The anæmia due to cancer is generally most marked when the intestine or stomach is affected, in which case it may be very profound (*v.* sup.). In several cases of extensive sarcoma I found practically no change in the blood. I have examined the blood in four cases of myxœdema; in one of these there was some cachexia, and the usual changes of secondary anæmia were found in slight degree; in the others there was no change worthy of note. Of three cases of exophthalmic goitre I found in the blood of one the changes found frequently in chlorosis; in the others there was no change, thus showing that the condition is independent of anæmia. In three cases of diabetes the number of the leucocytes was diminished; the blood-plates were generally increased, but not always.

In other conditions, such as pleurisy, acute Bright's disease, subacute rheumatism, &c., I found no constant alteration.

General Summary of Pathological Changes.

I. *Red corpuscles*—(a) *Variations in Size.*—Corpuscles slightly undersized, of which there is always a small number in normal blood, become increased in number when the number of the corpuscles is diminished. In traumatic anæmia their number may be little increased if the anæmia is acutely produced, but they become very numerous if it is chronic. They are specially numerous in the anæmia associated with cancerous cachexia, &c., but may also be abundant in chlorosis, pernicious anæmia, and leucocythæmia. If the anæmia be intense, some of the corpuscles may be very small—3–5 μ. These are rarely biconcave, often biconvex, and a very common condition is a deep concavity on one side of the corpuscle, with a corresponding convexity on the other, apparently formed by a folding of the corpuscle. Such corpuscles are common in pernicious anæmia, but may be seen in other forms. Megalocytes were found especially in pernicious anæmia, the presence of many corpuscles 9–12 μ in diameter being a striking feature in that disease. Very many of the largest corpuscles were oval in shape, and reached sometimes 16 μ in their long axis. Over-sized corpuscles may occur also in other forms of anæmia, though in severe secondary anæmia they are comparatively rare. I cannot

agree with Hayem that they become more numerous as the anæmia becomes more intense, whatever be its nature, for in the severest forms of secondary and traumatic anæmia and of leucocythæmia, the number of corpuscles being about 1,000,000, they were very scanty.

(b) *Irregularities in Shape.*—Poikilocytes are of much more frequent occurrence than is generally supposed, and may be found in all varieties of severe anæmia. (In this respect my results confirm those of Gram.) Their appearance in the blood, though commoner in the severer cases, cannot be said to have a definite relation to the number of corpuscles. This will be seen at once on examination of the tables of traumatic and secondary anæmia. In pernicious anæmia the presence of large numbers is very common, and they are then associated with great variations in the size of the corpuscles (3–12 μ). In chlorosis poikilocytes are very often seen, though sometimes they are scanty. I have, however, never failed to find them in well-marked cases. They may be present when there is very little reduction in the number of corpuscles; and one often sees in such conditions typical poikilocytes lying here and there between rouleaux of corpuscles of nearly normal size and appearance. In secondary anæmia they are rarely seen till the number of corpuscles has fallen below 3,000,000 per c.mm., and they are generally pale and of small size, and associated with a great number of undersized corpuscles. A similar statement applies to traumatic anæmia of a chronic nature, in one case of which (Case 3) their number was greater than in any case I have seen, some of them being extremely minute and delicate (*v.* Pl. IX. fig. 7). Poikilocytes may also be seen in considerable numbers in leucocythæmia.

(c) *Nucleated Red Corpuscles.*—Up to the present I have found nucleated red corpuscles in twelve cases—four cases of pernicious anæmia, six cases of leucocythæmia, one case of traumatic anæmia, and one of secondary anæmia complicated by hæmorrhage (some of which are not included in the tables). In six of these—two of pernicious anæmia, three of leucocythæmia, and one of traumatic anæmia—they were in considerable numbers; in the others they were few, and often could be found only after careful seeking. In most of the cases the number of

red corpuscles was about a million per c.mm., but I have seen them in considerable numbers in leucocythæmia, when the red corpuscles numbered nearly 3,000,000. In traumatic anæmia, and generally in leucocythæmia, they were quite circular (8–8·5 μ), and possessed a single nucleus of characteristic structure (*v.* fig. 8), whilst in pernicious anæmia they were often of large size and slightly irregular shape, with a nucleus presenting various appearances, as described above (*v.* Pl. IX. figs. 9, 10). In leucocythæmia I frequently saw forms containing two or even three round nuclei of small, generally unequal, size.

(d) *Minor Variations.*—A tendency to early crenation was found in many cases of anæmia—especially in those due to malignant disease, &c.—and a peculiar soft, almost semi-fluid condition of the red corpuscles (as Hayem describes) was seen in a case of suppuration with waxy disease, and to a less extent in other cases of suppuration. This softness was also seen to an extraordinary degree in a case of malignant jaundice. A remarkable adhesiveness (without softness) of the red corpuscles was noticed in acute pneumonia, and in a case of malarial anæmia the red corpuscles had a striking tendency to become folded in a variety of ways.

I saw none of "Eichorst's corpuscles" in any of the cases of pernicious anæmia.

II. *The Leucocytes.*—The leucocytes varied in number from 1000 per c.mm. in a case of pernicious anæmia to 687,500 per c.mm. in a case of leucocythæmia. In addition to leucocythæmia, their number was found to be increased in the following conditions:—

1. In some cases of lymphadenoma.
2. In suppuration, acute and chronic.
3. In certain "septic" conditions, *e.g.*, cancrum oris and malignant jaundice.
4. In some other cases of high temperature unattended with suppuration, *e.g.*, pneumonia and broncho-pneumonia.
5. In certain cases of secondary anæmia, especially in those due to cancer, chronic lead poisoning, &c.
6. In traumatic anæmia, especially shortly after the hæmorrhage.

They were decreased in number—

1. In pernicious anæmia, and some other forms of idiopathic anæmia. In many cases this alteration was very marked.
2. In cases of chlorosis and allied conditions in females.
3. In three cases of diabetes. Whether this is an invariable condition I cannot yet say.

The following general statements may be made regarding the characters of the leucocytes in these various conditions. In leucocythæmia (of which I have now examined eight cases) the increase is sometimes almost exclusively on the part of the uninucleated corpuscles (*v.* Pl. IX. fig. 4), which may either show great variations in size (6–12 μ), or be of nearly uniform size. In such cases the number of multinucleated leucocytes may even be absolutely decreased, though not usually. In other cases of leucocythæmia an increase of multinucleated leucocytes is seen along with a great number of large uninucleated leucocytes (11–15·5 μ), whose characters are described above, and many coarsely granular corpuscles, whose granules stain deeply with methyl-blue (*v.* Pl. IX. fig. 3).

In some cases of lymphadenoma with slight leucocytosis the proportion of uninucleated forms was increased, whilst in others all forms of leucocytes were more numerous than normal. With regard to other conditions, it may be given as a general rule that wherever there is leucocytosis, the proportion of multinucleated forms is increased; and I also found that wherever the number of leucocytes was markedly diminished, as in some cases of chlorosis and pernicious anæmia, the proportion of multinucleated forms was also diminished, so that the number of the uninucleated forms, though not absolutely fixed, varies less than of the multinucleated. The proportion of multinucleated forms was highest in cases of suppuration and in conditions such as cancrum oris, &c. The extremes in the proportion of the uninucleated to multinucleated forms, if we except leucocythæmia, were 1:·22 in a case of spontaneous anæmia and 1:13·5 in a case of empyema, *i.e.*, the multinucleated corpuscles varied from 18 to 93 per cent. of all the leucocytes. In some cases of leucocythæmia, however, their percentage was as low as 2 per cent. Also, when there is leucocytosis, especially if acute, there are found more intermediate forms between the two varieties, and there are proportionally fewer corpuscles in which the nuclei

are quite separate from one another, *i.e.*, in suppuration, &c., a greater number of the corpuscles appear to be of younger age or more recent formation. On the other hand, when the multinucleated corpuscles are specially diminished, intermediate forms are very scarce.

In some cases of wasting disease, such as cancer, phthisis, &c., there was found an increase in the proportion of multinucleated leucocytes without leucocytosis.

Coarsely granular leucocytes, whose granules stained deeply with methyl-blue, were numerous in some cases of leucocythæmia, as already noted, and in a case of malarial anæmia. Eosinophile corpuscles were numerous in some cases of leucocythæmia, in others not.

III. *Blood-Plates.*—Their number varied from 7000 per c.mm. in a case of pernicious anæmia and one of leucocythæmia to 1,210,000 in another case of leucocythæmia. Increase of their number was found in the following conditions:—

1. In traumatic anæmia, especially if of chronic nature (maximum noted = 734,000).
2. In secondary anæmia due to malignant disease, lead-poisoning, phthisis, &c. (maximum = 550,000).
3. In chlorosis (maximum = 598,000).
4. In some cases of leucocythæmia — in one case to an enormous extent.
5. In some cases of lymphadenoma, in which there was a slight increase in the number of leucocytes.
6. In some cases of high temperature with leucocytosis, notably in acute suppuration.

They were diminished in number—

1. In severe spontaneous anæmia, notably in typical cases of pernicious anæmia (in many of which their number was 8000–15000).
2. In severe malarial anæmia of persistent nature.
3. In some cases of leucocythæmia, chiefly (if not exclusively) in those in which the leucocytes were nearly all of the uninucleated variety (minimum = 7000).
4. In some cases of high temperature, acute rheumatism, &c., but in none of these was the diminution very marked.

5. In some miscellaneous conditions, *e.g.*, in two cases of cirrhosis of the liver, in a case of huge abdominal sarcoma, in which there was diminution of leucocytes, &c.

The following alterations in their number during the progress of cases were noted.

In traumatic anæmia their number diminished as the number of red corpuscles returned to the normal.

In cases of pernicious anæmia, of chlorosis, and of malarial anæmia (Cases 13, 14, 34, 47; though in the third of these the number was about normal at the first observation), their number increased as improvement took place, generally more so proportionately than the number of the red corpuscles.

In a case of leucocythæmia (Case 53), where their number was nearly normal at the first observation, they decreased greatly, till, shortly before the death of the patient, they were exceedingly scanty.

In some cases of high temperature with leucocytosis (Cases 62, 63), they increased in number with the leucocytes, and in the latter case their number fell with that of the leucocytes, though rather more slowly.

The blood-plates were in some cases of larger size than usual, principally in some cases of chlorosis.

The significance of these changes is discussed later.

EXPERIMENTAL.

The following experiments were performed in order to determine the changes produced in the blood and blood-glands of healthy animals as a result of hæmorrhage, and especially to determine whether the blood-plates play any part in the regeneration of the red corpuscles. The blood was examined for several days before, and generally on each day after the hæmorrhages, by all the various methods, and after the death of the animal, the cells of the bone-marrow, &c., were examined in a similar way. The results are given in a condensed form.

In all the experiments the animals were anæsthetised.

EXPERIMENT I.

The object of this experiment was to observe the changes produced in the blood by a single large hæmorrhage, the amount of blood removed being nearly 2 per cent. of the body weight. Examinations of the blood for several days beforehand showed an almost constant condition of the corpuscular elements as regards both numbers and characters.

Dog, weight = 6·3 *kilo.*

Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.	Poikilocytes.	Nucleated Red Corpuscles.
Jan. 17.	7,460,000	13,000	381,000	1:2·1	None.	None.
,, 18.	7,296,000	12,000	394,000	...	,,	,,
,, 20.	7,558,000	10,500	382,000	...	,,	,,
,, 21.	7,355,000	11,500	426,400	1:2	,,	,,
H.						
	*6,508,000	26,500	313,000	1:4·1	,,	,,
,, 22.	5,797,000	21,500	369,000	1:4·6	,,	,,
,, 23.	6,176,000	23,000	397,200	1:4·1	,,	,,
,, 24.	6,686,000	24,500	386,000	1:3·5	,,	,,
,, 25.	6,902,000	25,500	380,000	...	,,	,,
,, 27.	6,944,000	18,000	...	1:3·3	,,	,,
,, 28.	7,361,000	19,500	384,000	...	,,	,,
,, 29.	7,563,000	10,500	461,000	...	,,	,,
Feb. 1.	7,532,000	10,000	450,400	1:2·9	,,	,,

H, January 21st, 12.45 P.M., animal bled; 120 c.c. blood withdrawn.
* ,, 2.45 P.M., blood examined.

It will be seen from the table that two hours after the bleeding the number of *red corpuscles* had fallen considerably, while that of the leucocytes showed a marked increase. The red corpuscles reached their minimum number on the day after, and the original number was regained within seven days. During the time of regeneration the red corpuscles were practically unaltered in shape and size, slightly under-sized corpuscles being scarcely more numerous than in normal conditions. I noticed in dried films stained with methyl-blue that some of them stained rather more deeply than the others, but no nucleated red corpuscles were seen. The *blood-plates*, contrary to what I expected, were diminished in number during the period of regeneration of the red corpuscles, and none of them were of larger size than usual. The *leucocytosis*, which was very marked, was found to be due almost entirely to an increase of the multinucleated leucocytes, forms intermediate between those and the uninucleated corpuscles being also more numerous.

There was therefore no distinct change in the blood in this experiment which would indicate that regeneration was going on, though the restoration of the red corpuscles took place very rapidly.

Experiment II.

In this experiment, by means of two bleedings, a much more intense anæmia was produced, so that the number of the red corpuscles fell to 37 per cent. of the original number. The animal was killed when the blood showed definite signs of regeneration.

Dog, weight = 6·8 *kilo.*

Date.	Red Corpuscles.	Leucocytes.	Blood-plates.	Prop. A.	Poikilocytes.	Nucleated Red Corpuscles.
Jan. 16.	6,698,000	7,000	128,000	1:2	None.	None.
,, 18.	6,375,000	7,500	185,600	...	,,	,,
,, 20.	6,425,000	10,000	206,000	...	,,	,,
,, 25.	6,350,000	15,000	164,000	...	,,	,,
,, 27.	6,309,000	7,500	146,000	1:1·8	,,	,,
	H^1					
	*6,400,000	8,000	132,000	1:1·7	,,	,,
,, 28.	5,461,000	26,500	129,200	1:4·6	,,	,,
,, 29.	3,975,000	21,000	138,000	1:4·6	,,	,,
,, 30.	3,840,000	21,000	200,000	1:2·9	,,	,,
,, 31.	3,938,000	11,500	189,000	1:1·9	,,	Present.
	H^2					
Feb. 1.	2,447,000	29,500	285,000	1:4·9	,,	,,
,, 2.	2,480,000	27,500	...	...	,,	,,
,, 3.	2,451,000	27,000	345,000	1:4·8	,,	,,
,, 4.	2,664,000	27,000	411,000	1:4·1	,,	,,
,, 5.	2,513,000	27,000	403,000	1:3·6	,,	,,
,, 6.	2,762,000	26,000	489,000	...	,,	,,
,, 7.	2,922,500	19,000	401,000	...	,,	,,
,, 8.	2,975,000	15,000	...	1:2·8	,,	,,
,, 10.	3,311,000	17,000	400,000	1:2·9	,,	,,

H^1 Jan. 27, 12·15 P.M., 145 c.c. blood withdrawn.
* ,, blood examined immediately after.
H^2 Feb. 1, 1 P.M., 120 c.c. blood withdrawn.

During the anæmia the *red corpuscles* became of softer consistence, and tended to adhere together in irregular heaps. A few were 6–7 μ in diameter, but very small forms were not seen. (These changes were seen after the first hæmorrhage, but were more marked after the second.) No true poikilocytes were seen. A few nucleated red corpuscles were found in the blood on January 31 and on subsequent days, being most numerous about February 5. The perinuclear portion of these corpuscles stained slightly more deeply than the ordinary corpuscles, but a few of the latter were found to stain in a similar manner. The *blood-plates* increased greatly in number after the second hæmorrhage, and some were of larger size, reaching 4 μ in diameter. Their characters, however, did not approach those of the red corpuscles; on the contrary, they broke down more readily than usual. The *leucocytes* showed the same changes in a marked

degree, as in Experiment I.; but it is noticeable that *immediately* after the first hæmorrhage the number of leucocytes, as well as of red corpuscles, was unaltered.

The animal was killed under ether on February 10. As the blood-plates were very numerous at the time of death, a favourable opportunity was apparently presented for determining their origin. Before killing the animal I made a small puncture in the spleen, and examined the blood flowing from it by the usual methods. In this blood the blood-plates appeared much more numerous than in the blood taken in the usual way from the ear of the animal. They were, however, of uniform character, and had the usual staining reactions. The colourless cells apparently comprised the leucocytes of the blood and cells added from the spleen, some of the latter being of much larger size (12 μ) than the former. Nucleated red corpuscles were fairly numerous.

In the blood of the splenic vein the number of leucocytes seemed scarcely more numerous than in the arterial blood; but the proportion of uninucleated corpuscles was much higher, these cells being, in fact, as numerous as the multinucleated forms. Immediately after the death of the animal, examination of the spleen pulp showed blood-plates in very small number, *i.e.*, they had belonged to the blood in the organ rather than to the spleen pulp itself. Nucleated red corpuscles were seen, but they were comparatively few in number. In the splenic vein colourless cells were found in larger numbers than during life, and could be still further increased by slightly squeezing the spleen. This probably explains the statement of some observers, that leucocytes are much more numerous in the splenic vein than in the artery.

Red marrow filled the shafts of the long bones, but as this is the normal condition in dogs of this class, the occurrence is of no importance. A large number of nucleated red corpuscles were found in the marrow taken from various bones, but they appeared to be more numerous on the shaft of the femur than in the short bones. They were of the usual appearance, the nucleus being, as a rule, about 4 μ in diameter, and some were in process of division. In one or two the nucleus was seen half protruded from the cell, within a few minutes after the death of the animal. The amount of hæmoglobin seemed to vary much, and I saw also cells of the same structure, but in whose perinuclear protoplasm no yellow colour could be detected. There was also a great increase in the number of cells containing pigment, which in some occurred in fragments, in others more in a diffuse form. (This condition was not found in any other experiments.) No alterations in any of the other cells could be detected. Blood-plates were very few in number.

In the lymphatic glands (examined by dissociation) the blood-plates were very few, and might be accounted for by the blood left in the blood-vessels of the glands. I saw, however, many small round lymphoid bodies (3–4 μ), which became transparent on the addition of acetic acid, unlike the nuclei of the lymph corpuscles. No nucleated red corpuscles were found.

Experiment III.

In this experiment the same animal was employed as in Experiment I., and I endeavoured, by means of three hæmorrhages, to produce a still greater anæmia than in Experiment II. The minimum number of red corpuscles was, however, practically the same, viz., 38 per cent. of the normal.

Dog, weight = 6·2 *kilo.*

Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.	Poikilocytes.	Nucleated Red Corpuscles.
Feb. 6.	7,320,000	14,800	408,000	1:2	None.	None.
,, 7.	7,455,000	19,500	398,000	1:2·1	,,	,,
	H¹					
	*5,866,000	26,500	334,000	1:4·9	,,	,,
,, 8.	5,520,000	22,000	300,000	1:4·3	,,	,,
,, 9.	5,408,000	26,000	...	1:3	,,	,,
,, 10.	5,672,000	19,000	350,000	1:2·8	,,	,,
,, 13.	5,870,000	14,000	396,000	1:2·1	,,	,,
	H²					
..	**5,109,000	25,000	...	1:3·9	,,	Present.
,, 14.	4,352,000	17,000	316,000	1:3·1	,,	,,
,, 15.	4,566,000	15,500	298,000	...	,,	,,
,, 16.	4,835,000	9,000	377,200	...	,,	,,
	H³					
,, 17.	4,400,000	19,500	...	1:4·4	,,	,,
,, 18.	3,753,000	13,500	350,000	1:3·4	,,	,,
,, 19.	2,884,000	10,500	400,000	1:2·6	,,	,,
,, 20.	2,929,000	11,500	484,000	1:2	,,	,,
,, 21.	3,018,000	10,500	380,000	...	,,	,,
,, 22.	3,523,000	13,000	..	...	,,	,,
,, 24.	4,280,000	10,000	400,000 (?)	1:2·1	,,	,,

H¹, Feb. 7, 1 P.M., 150 c.c. blood withdrawn.
* ,, 5 P.M., blood examined.
H², Feb. 13, 12.30 P.M., 140 c.c. blood withdrawn.
** ,, 5 P.M., blood examined.
H³, Feb. 16, 1.15 P.M., 140 blood c.c. withdrawn.

During the whole course of the anæmia the *red corpuscles* remained practically unaltered in size and shape, and none were found of smaller diameter than 6·5 μ. Nucleated red corpuscles were found after the second bleeding till the death of the animal. No true poikilocytes were found.

Thenumber of the *blood-plates* fell after the first hæmorrhage, and did not rise above the normal till after the third. Even then they were all of the usual size, and were unaltered in character. A *leucocytosis* occurred after each hæmorrhage, and was of the same nature as in previous experiments.

The rate of regeneration of the blood (as in Experiment I.) is re-

markable, and the absence of very small red corpuscles in the blood during the period of regeneration is also worthy of note.

On 26th February, when I intended to perform some experiments before killing the animal, it suddenly died under the anæsthetic. The red marrow was found on microscopic examination to contain a very large number of nucleated red corpuscles; they were, in fact, more numerous than in any specimen of marrow I have ever examined. On examination in the methyl-violet salt solution a great number were seen in every field of the microscope. Their size was 7–9 μ, and the nucleus generally 4–5 μ in diameter, with a distinct reticular structure, in some much smaller and more homogeneous. A considerable number were in process of division. Cells of the same structure, but apparently colourless, were also seen. Blood-plates were very few in number. A few nucleated red corpuscles were seen in the splenic pulp and also in the splenic vein. Nothing worthy of note was found in the lymphatic glands.

The chief interest in this experiment is in the fact that a very active power of regeneration of red corpuscles was associated with a specially large number of nucleated red corpuscles in the bone-marrow.

Experiment IV.

Though in many respects a repetition of Experiment II., this experiment presents certain points of special interest.

Dog, weight = 4·8 kilo.

Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Prop. A.	Poikilocytes.	Nucleated Red Corpuscles.
Mar. 12.	5,830,000	19,800	408,000	1:2	None.	None.
,, 13.	5,955,000	23,500	398,000	...	,,	,,
	H[1]					
,, 14.	3,372,000	28,000	480,000	...	,,	,,
,, 15.	3,425,000	26,500	456,000	1:4·2	,,	,,
,, 17.	3,546,000	21,300	550,000	...	,,	,,
	H[2]					
,, 18.	2,525,000	33,000	471,000	1:5	A few.	Present.
,, 19.	2,555,000	23,000	450,000	1:3·7	,,	,,
,, 20.	2,676,000	21,000	487,000	...	,,	,,
,, 21.	2,681,000	16,000	400,000	..	,,	,,
,, 22.	3,100,000	20,000	...	1:3	,,	,,
,, 25.	3,362,000	17,000	328,000	...	,,	,,
,, 26.	3,379,000	10,000	304,000	...	,,	,,

H[1] March 13, 1 P.M., 130 c.c. blood withdrawn.
H[2] March 17, 1.30 P.M., 115 c.c. blood withdrawn.

During the height of the anæmia (about 19th March) the *red corpuscles* showed greater variations in size (6 μ–8·5 μ) than in the previous experiments, and a few poikilocytes were also seen. Some of the *blood-plates* were also seen to be of larger size. On 17th March some

were 4 μ in diameter, and on 26th March some measured 6 μ by 5 μ, the larger forms being of oval shape. I accordingly compared the characters of the red corpuscles and blood-plates by a variety of methods of staining, &c., but found them as distinct from one another as in normal circumstances. This is the only occasion during the experiments in which I saw blood-plates as large as the smallest red corpuscles.

On 27th March, before killing the animal, I examined the blood of the splenic artery and vein, as well as the blood taken directly from the spleen by a small incision in its capsule. The results are:—

Blood of	Leucocytes.	Blood-Plates.	Prop. A.
Splenic artery, . . .	24,400	197,000	1:2·9
Spleen, ...	30,800	325,000	1: ·8
Splenic vein, . . .	25,200	302,000	1:1·1

Nucleated red corpuscles were seen in the blood taken from all three situations, and were as numerous in the artery as in the vein. In the blood taken directly from the spleen they were present in nearly the same number, and I saw one in which the process of division was almost completed. The difference in the proportion of the two varieties of leucocytes was very marked, and has already been referred to (p. 359). After allowing for the sources of error in enumerating the blood-plates, I was convinced that in this and Experiment II. the blood-plates were more numerous in the blood of the splenic vein and of the spleen itself than in the arterial blood. All the blood-plates had the usual characters. Few were found in the splenic pulp *post-mortem*.

The bone-marrow showed a similar condition to that found in the previous experiment, but the nucleated red corpuscles were less numerous.

Experiments V. and VI.

I have given the results of these experiments on rabbits together, as they were practically similar. As the animals did not stand the operation so well as dogs, only one bleeding was practised.

In both cases the blood underwent similar changes after the hæmorrhage. The *red corpuscles* showed more variation in size (6 μ–8·5 μ), and became softer in consistence. Some of them also stained more deeply than the others. No nucleated red corpuscles and no true poikilocytes were seen. The *blood-platès* increased in number, reaching their maximum in both cases on the seventh day after the operation, but none were found to exceed 3 μ in diameter. The *leucocytes* were increased in number, especially the multinucleated forms, but it was found difficult to estimate the proportion of the two varieties owing to the large number of granules in the protoplasm of the leucocytes, which often obscured the nuclei.

	Date.	Red Corpuscles.	Leucocytes.	Blood-Plates.	Poikilocytes.	Nucleated Red Corpuscles.
Rabbit I.,	Feb. 30.	5,818,000	24,500	508,000	None.	None.
weight	Mar. 1.	5,863,000	21,000	610,000	,,	,,
2·2 kilo.		H¹				
		*5,338,000	21,000	...	,,	,,
	,, 2.	3,364,000	23,500	682,000	,,	,,
	,, 3.	2,722,000	30,000	696,000	,,	,,
	,, 4.	3,080,000	25,000	660,000	,,	,,
	,, 5.	3,045,000	13,000	530,000	,,	,,
	,, 7.	3,571,000	11,500	836,000	,,	,,
	,, 8.	4,218,000	11,000	847,000	,,	,,
	,, 10.	4,445,000	10,250	768,000	,,	,,
Rabbit II.,	Mar. 12.	6,501,000	10,000	563,000	None.	None.
weight	,, 13.	6,091,000	9,000	450,000	,,	,,
1·85 kilo.	,, 14.	6,181,000	9,000	486,000	,,	,,
		H²				
	,, 15.	3,531,000	21,000	484,000	,,	,,
	,, 17.	3,235,000	15,000	620,000	,,	,,
	,, 18.	2,846,000	11,000	582,000	,,	,,
	,, 20.	3,490,000	8,000	740,000	,,	,,
	,, 21.	3,455,000	8,000	762,000	,,	,,
	,, 22.	3,701,000	8,500	741,000	,,	,,
	,, 24.	4,075,000	7,000	686,000	,,	,,

H¹ Mar. 1, 12.30 P.M., 45 c.c. blood withdrawn.
* Blood examined immediately after.
H² Mar. 14, 1 P.M., 40 c.c. blood withdrawn.

Post-mortem.—It was found that in the bone-marrow the number of nucleated red corpuscles was greatly increased, and a large proportion were in process of division. Some of them were considerably larger than the ordinary red corpuscles, and were less coloured with hæmoglobin. It appeared as if smaller corpuscles were produced by division, and the hæmoglobin increased at the same time. There were also cells of the same structure in which no hæmoglobin could be detected. No nucleated red corpuscles were found in the spleen or in any other part of the body. Examination of the blood of the splenic vein, and the blood obtained by making a small incision in the spleen, gave the following results:—

	Blood of	Leucocytes.	Blood-Plates.
Rabbit I., ...	Spleen . .	11,500	804,000
	Splenic vein .	8,300	756,000
Rabbit II., ...	Spleen . .	11,500	744,000
	Splenic vein .	6,500	736,000

The arterial blood was not examined at the same time, but at an earlier period on the same day (*v.* table above). These results confirm

those found in the case of the dog (Exp. IV.). The proportion of uninucleated leucocytes in the vein was also higher than in the arterial blood.

General Summary and Conclusion.

The withdrawal of blood from the vessels may be said to produce effects in the following ways:—Firstly, it reduces the volume of circulating blood, the fluid portion of which is restored much more rapidly than the corpuscles are; secondly, it calls regenerative processes into play (of this we have distinct evidence); and, thirdly, especially if there be several hæmorrhages, it brings about an impoverished condition of the blood-serum, which may cause alterations in the corpuscles. These facts must be kept in view in considering the changes found in the blood.

When a large quantity of blood, say 2–3 per cent. of the body-weight, is withdrawn from a dog, and an enumeration of the red corpuscles is made immediately after, I have found no diminution in their number. After a few hours their number has decreased somewhat, and within twenty-four hours the decrease is very marked. The operation of bleeding was performed on dogs eight times in all, and in five of these cases the minimum number of red corpuscles was observed on the day after, in two cases on the second day, and in the remaining case on the third day after. Lyon,[1] in a series of experiments on dogs, found that the minimum was reached in 2–6 days after the hæmorrhage, and Hünerfauth[2] in 1–9 days after, but in their cases larger quantities of blood were removed, 3·5–5 per cent. of the body-weight. In some of their experiments a slight decrease in the number of red corpuscles was found immediately after the bleeding, but this might be explained by the fact that the operation extended over a longer time, so that absorption of fluid might already have advanced at the time of enumeration. The decrease in the number of red corpuscles per c.mm. takes place by the addition of fluid to the blood, and it is interesting to note that in Experiments I. and III., where much fluid was supplied by the animals being allowed to drink milk copiously after the bleeding, the anæmia supervened more rapidly. In

[1] Lyon, "Blutkörperchenzählungen bei traumatischer Anämie," *Virchow's Archiv*, Bd. lxxxiv. p. 207.

[2] Hünerfauth, "Einige Versuche über traumatische Anämie," *Virchow's Archiv*, Bd. lxxvi. p. 310.

Experiment V., performed on a rabbit, the decrease in the number of red corpuscles after the bleeding was considerable, and Hünerfauth and Vierordt[1] also found that in rabbits the number of corpuscles fell much more rapidly than in dogs.

Shortly after the hæmorrhage the number of leucocytes increases greatly, so that within a few hours their number is sometimes more than doubled. The maximum number is generally reached on the day of the bleeding or on the day after, and in the course of a few days their number has returned to normal. Accordingly the leucocytosis is not associated with the regeneration of the red corpuscles, but with the period during which the fluid portion of the blood is being restored. I found that immediately after the hæmorrhage there was no increase in the number of leucocytes, so that it cannot be due, as some have supposed, to the leucocytes passing out of the vessels less freely than the red corpuscles. (Lyon's results closely agree with what I have stated.) An important point is that the increase in the number of leucocytes is almost exclusively on the part of the multinucleated forms (*v.* Tables), and we have thus the interesting fact that multinucleated leucocytes equal in number to all the leucocytes of the blood may be added to the blood a few hours after a hæmorrhage. As these corpuscles are present in large numbers only in the blood in normal circumstances, there must be either a multiplication by division or a formation of them from uninucleated forms, the latter supposition being much the more probable. It is well known that after hæmorrhage the blood-pressure is maintained by contraction of the small arteries, and it is possible that at the same time there is a contraction of the spleen, and more leucocytes may pass into the blood from the pulp and undergo the transformation. The large increase of leucocytes cannot, I think, be satisfactorily explained by a supposed increase of the flow of lymph into the blood.

With regard to the blood-plates, it may be stated that in most of the experiments their number was increased during the period of regeneration of the red corpuscles, but this was not the case invariably, *e.g.*, Experiment I. affords a striking exception. In two cases (Experiments II. and IV.) their size was increased somewhat, but in the others it was unaltered. It was thus clearly

[1] Vierordt, *Archiv d. phys. Heilkunde*, Bd. xiii. I have only seen a reference.

proved that active blood-formation might be going on without the blood-plates being more numerous than usual or of larger size. It was also found that when they were increased in size their characters were quite distinctive, and no intermediate forms could be found between them and the red corpuscles. I have therefore come to the conclusion that there is no evidence that the blood-plates ever develop into red corpuscles, and that accordingly Hayem's theory is quite untenable. The increase of the blood-plates is most marked in cases of chronic anæmia due to many hæmorrhages, and is, I am inclined to believe, to be associated with the impoverished condition of the blood rather than with its regeneration, though at present I cannot explain the connection. Variations in the size and irregularities in the shape of the red corpuscles were found to be neither very marked nor very numerous, the latter being present only in Experiment IV. These experiments show that the number of red corpuscles may be rapidly increasing while the size of the corpuscles is practically unaltered, and that young corpuscles in the blood are not necessarily of small size. Like the increase in the number of the blood-plates, the changes in size and shape of the red corpuscles are especially found in the chronic anæmias, and are not to be associated with blood-formation. An increased softness and diminished elasticity of the red corpuscles were noticed in the severer cases, and were probably caused by the altered condition of the blood-serum.

The most important phenomenon observed in the blood after hæmorrhage, and the one specially related to the regeneration of the red corpuscles, was the appearance of nucleated red corpuscles. These were seen in the blood of dogs in all cases in which the number of red corpuscles fell below 50 per cent. of the normal. I did not find them in the blood of rabbits, but the anæmia produced in these animals was not so great as in dogs. Afanassiew in similar experiments on dogs also found them, and even in larger numbers. (Their occurrence in the human subject has already been noted, *v. supra.*) These corpuscles exactly resembled in structure the nucleated red corpuscles found in the blood in fœtal life and those in the red bone-marrow of the adult, and were almost of the same size as the ordinary red corpuscles. When stained with methyl-blue,

the perinuclear portion stained of a distinctly green colour, but rather more deeply than most of the non-nucleated forms. I have, however, noted the fact that some of the latter stained in the same way, and were probably those which had most recently lost the nucleus.

With regard to the blood-forming organs, the most important change was an increase of the number of nucleated red corpuscles in the bone-marrow, and also of forms in course of division. This change has been noted by a number of observers, *e.g.*, Geelmuyden,[1] Lockhart Gibson,[2] Litten and Orth,[3] &c. I may also add that I found in the bone-marrow of a patient, who had died from long-continued hæmorrhage, an extraordinary number of nucleated red corpuscles, though not so great as in a case of Neumann's,[4] in which they were as numerous as all the colourless cells together. The result of severe hæmorrhage, therefore, is that there is an increase of the nucleated red corpuscles normally present in the bone-marrow, and some may appear in the blood. How is this change brought about? Denys[5] has shown, and my own observations confirm this, that in the marrow of birds the younger red corpuscles lie at the periphery of wide venous capillaries, in which there is a flowing current only in the centre. He has also shown that after hæmorrhage the zone of young corpuscles becomes broader, and some pass into the central stream. I believe that an analogous condition obtains in the marrow of mammals. The nucleated red corpuscles probably lie at the periphery of similar capillaries, or in spaces which are practically diverticula, and only pass into the blood-current when it has become poor in corpuscles.

A similar explanation is probably applicable to the occurrence of nucleated red corpuscles in the blood, and to the alterations of the marrow in many cases of pernicious anæmia,[6]

[1] Geelmuyden, "Das Verhalten des Knochenmarkes in Krankheiten," *Virchow's Archiv*, Bd. cv. p. 136.

[2] Gibson, *Jour. of Anat. and Phys.*, vol. xx. p. 107.

[3] Litten and Orth, "Ueber Veränderungen des Marks in Röhrenknochen," *Berlin. Klin. Woch.*, 1877, p. 743.

[4] Neumann, "Ueber Blutregeneration u. Blutbildung," *Zeitschr. f. Klin. Med.*, Bd. iii. p. 411.

[5] Denys, *La structure de la moelle des os. La Cellule*, Tome iii.

[6] *Vide* Cohnheim, *Virchow's Archiv*, Bd. lxviii. p. 291; Neumann, *Berlin. Klin. Woch.*, 1877, p. 685; Geelmuyden, Litten and Orth, *Op. cit.*

as it is now the opinion of many that the marrow changes only compensate for the destruction of red corpuscles. In leucocythæmia, however, we may find many nucleated red corpuscles in the blood when there is comparatively little anæmia, and in these cases there must be an important disturbance of the vascular arrangements by which the nucleated red corpuscles are prevented from passing into the circulation in normal conditions.

With regard to the manner in which the nucleated red corpuscle loses its nucleus, there has been, and still is, great diversity of opinion. I have been inclined to believe that Neumann's[1] theory, according to which the nucleus atrophies and finally disappears, is the correct one; yet it must be admitted that the number of corpuscles with a nucleus in the atrophied condition is smaller than one would expect. According to Rindfleisch,[2] the nucleus passes out of the cell surrounded by a small quantity of protoplasm, and the perinuclear portion becomes the adult corpuscle. Such an appearance may certainly sometimes be seen, but it must be interpreted with caution, as the nuclei of nucleated red corpuscles may by mechanical pressure be very easily made to pass out of the corpuscles. In cases in which nucleated red corpuscles occurred in the blood, I have not found any free nuclei in the blood, though Ehrlich[3] mentions their presence in the blood of an anæmic patient. This observation, if correct, tends rather to confirm Rindfleisch's theory, which has also been supported in a slightly modified form by Howell,[4] in a recent paper on the development of blood corpuscles. I have seen no evidence that the ordinary red corpuscle is formed as a bud from the perinuclear portion of the nucleated red corpuscle, as Malassez[5] has described and figured.

Whilst it is practically admitted by all observers that the nucleated red corpuscles of the bone-marrow multiply by indirect

[1] Neumann, *Archiv d. Heilkunde*, 1869, p. 68.

[2] Rindfleisch, "Ueber Knochenmark und Blutbildung," *Archiv f. Mikr. Anat.*, Bd. xviii. p. 1.

[3] Ehrlich, *Charité-Annal.*, 1884, p. 109.

[4] Howell, *Journal of Morphology*, June 1890.

[5] Malassez, "Origine des globules rouges dans la moelle des os.," *Archives de Phys.*, 1882, p. 2.

division, I believe that they are also constantly being formed from colourless cells of similar structure, whose nuclei, though a little larger, present the same well-marked reticular appearance. These are the "erythroblasts" of Löwit and Denys.[1] They differ both in the character of the nucleus and in the appearance of the surrounding protoplasm from the uninucleated leucocytes. Bizzozero,[2] in a recent paper on the marrow of birds, says that these erythroblasts also differ from leucocytes, in their protoplasm containing hæmoglobin, though in small amount; but in the case of the dog's marrow, at least, I have failed by various methods to detect any hæmoglobin in many of them. I believe that Müller's[3] theory—that there are certain cells which in certain circumstances develop into red corpuscles, and in others into multinucleated leucocytes—is both insufficiently supported by evidence, and theoretically improbable. Whether or not red corpuscles are ever formed after birth in any other way than that described I am not prepared to say, but Neumann[4] has recently called attention to the interesting fact that quite new and distinct growths of red marrow, containing nucleated red corpuscles, may be formed in various conditions after birth, yet we have no evidence that either nucleated red corpuscles or their colourless predecessors are carried to those new centres.

The blood-plates are elements which properly belong to the blood, and not to the blood-forming organs. I failed to find them amongst the cells of lymphatic glands, and in the lymph of the thoracic duct, in which latter situation Hayem and Bizzozero also found them absent. Also in the splenic pulp and in the bone-marrow, examined immediately after death, they are found in very small numbers, though they may be present in great numbers in the blood circulating in those tissues during life, and I have been unable to trace their origin from any of

[1] Löwit, "Ueber die Bildung rother und weisser Blutkörperchen," from *Sitzb. d. k. Akad. d. Wis. zu Wien.*, Bd. lxxxviii. Abtheil. iii.

[2] Bizzozero, "Neue Untersuchungen über den Bau des Knochenmarks bei den Vögeln," *Arch. f. Mikr. Anat.*, Bd. xxxv.

[3] Müller, "Zur Frage der Blutbildung," *Sitzb. d. k. Akad. d. Wis. zu Wien.*, Bd. xcviii. Abtheil. iii.

[4] Neumann, "Ueber die Entwickelung rother Blutkörperchen in Neugebildetem Knochenmark," *Virchow's Archiv*, Bd. cxix. p. 385.

the cells in these organs. It will be seen from the above tables that the variations of the blood-plates in disease, both as regards decrease and increase, closely correspond with the multinucleated leucocytes; and especially the fact is to be noted that in the cases of leucocythæmia in which those leucocytes are increased in number, the blood-plates are also very numerous. Moreover, the fact that I found the latter more numerous in the splenic vein than in the artery, whilst the multinucleated leucocytes were fewer, would also tend to support the theory that they are the freed nuclei of these leucocytes. Yet the two elements, though closely agreeing in size, differ markedly in structure and in staining reactions, and I have not been able to convince myself that the blood-plates have this origin. The nuclei of nucleated red corpuscles differ still more strikingly from blood-plates, and, I believe, never become transformed into them. As they are therefore not nuclei unless these have the faculty of undergoing sudden transformation, the theory that they are discs of some albuminoid substance (Löwit) must not be entirely overlooked, though there are strong arguments against it. The difficulty of the problem is illustrated by the fact that Hayem[1] in his latest work suggests the possibility that they are derived from ordinary red corpuscles, but I have seen nothing in favour of this. I find no evidence that the blood-plates develop into any other higher structure; on the contrary, they most probably break down, and disappear in the circulating blood.

In conclusion, I have great pleasure in recording my indebtedness to those who have assisted me in my work. My best thanks are due to Professor Greenfield, who suggested this subject as a suitable one for research, and under whose superintendence the work was done; and also to Professor Rutherford for assistance and advice, chiefly in connection with the experimental part. I also take this opportunity to thank the Physicians and Surgeons of the Edinburgh Royal Infirmary, who have kindly allowed me to examine cases in their wards.

[1] Hayem, *Du Sang*, p. 588.

OBSERVATIONS ON SOME MAMMALIAN TASTE-ORGANS. By FREDERICK TUCKERMAN, *Amherst, Massachusetts.*

THE present communication contains the result of an examination of certain gustatory areas in some embryos and new-born individuals. The forms studied were *Mus musculus, Arctomys monax*, and *Mephitis mephitica*, the material consisting in each case of several specimens. No examination of the papillæ foliatæ was attempted.

Mus musculus (new-born).

The tongue possesses the general characters of the adult organ. Near the base, and situated in the median line, is a single, deeply-set, circumvallate papilla. The papilla is not as yet completely differentiated, nor is the trench wholly free from epithelial debris. The epithelium protecting the upper surface is, as in later life, thicker than that covering the lateral area. Both mucous and serous glands are present; but the latter, which are still in process of formation, only sparingly so. Glands of the serous type are not very abundant in the adult form. The ducts, as in the adult, open into the trench at its deeper part. The mucous glands are more plentiful, and are further advanced in their development, than the serous; and their ducts, which are nearly straight, lead directly to the free lingual surface. The taste-bulbs are few in number, and in their development are still incomplete. They are scattered quite irregularly at the upper part of the papilla, and lie partly in the stroma of the mucosa and partly in the epithelium. Here and there in the basal epithelium of the lateral area, as well as in the mucosa underlying, structural modifications of the cells and stroma were very evident, though no true bulbs were discernible. These changes suggest, and in all probability represent, the early stages in the development of the bulbs. I looked for similar changes in the corresponding region of the outer wall of the trench (bulbs being normally present here in

the adult form), but did not succeed in detecting any. The epiglottis and larynx were not examined.

Arctomys monax (new-born).

The main characteristics of the adult tongue were exemplified in all the specimens. They were all distinctly bifid at the tip, and their upper surface was impressed anteriorly by a deep median groove. In none of the specimens did there appear to be above three circumvallate papillæ, the number in the adult ranging from three to five. The width of the papillæ is about double the height, and their exposed area is covered with a thin layer of epithelium. They show many of the characters of later embryonic life. The differentiation is incomplete, the papillary and outer walls being still united throughout in most instances. Serous glands and ducts are not very plentiful in the adult form, and no traces of either were detected in these specimens. A few bulbs, more or less subepithelial in position, are present at the upper part of the papillæ, but none were observed on the lateral area. The total number of bulbs in the adult *Arctomys* is below the mean of the Mammalia. Some of the bulbs, judging wholly from their external structure, are quite well advanced, but much smaller than in the adult. One of the largest measured 0·021 mm. transversely, the mean of the same dimension in the fully-formed bulb of the adult being 0·032 mm. Only a few bulbs were observed in the fungiform papillæ, and they were for the most part small and immature. Bulbs were present in the epiglottis and elsewhere in the larynx, some of them being well developed and of good size for this period of life. They lie partly in the epithelium and partly in the mucosa. Mucous glands were quite abundant in this region, and were further advanced than those of the tongue.

Mephitis mephitica (embryo).

These embryos were apparently very near the term of their intrauterine life.

Neither papilla shows a tendency to become lobate. The trenches are not yet entirely free from epithelium, but the latter

is mostly confined to their deeper part. The serous glands and their ducts are not greatly advanced, nor do they appear to be very abundant. The papillæ bear many bulbs at their upper part, some of them being wholly epithelial in position. Where the trenches are open, the lateral area of the papillæ also contains bulbs; but they are scattered at irregular intervals, their lower portion resting in depressions of the mucosa. The bulbs of the upper surface are as usual the furthest advanced. In shape they are long and narrow, some of them being nearly fusiform, and appear to be more embryonic in structure and character than in position. They are fairly uniform in size, and measure about 0·036 mm. in length and 0·018 mm. in breadth. In the full-grown animal the mean length is 0·045 mm., and the mean breadth 0·028 mm. The papillæ are well supplied with nerves. At the upper part of the papillary axis they form a close network, from which fibrils can be traced directly to the bases of the bulbs, within which the outlines of the sensory cells are distinctly visible in many instances. The fungiform papillæ were fairly numerous, and most of those examined bore one or more bulbs at their upper part; but the latter are smaller and less advanced than those of the circumvallate papillæ. The bulbs, when single, lie vertically, directly in the long axis of the papilla. Where two are present they are disposed obliquely near the summit, with their apices directed upwards and outwards. In many of the papillæ the nerve-plexus is quite clearly defined; it is, however, less rich and somewhat coarser in texture than that of the circumvallate papillæ. There are certainly indications of bulb-like structure in the epiglottis, though a clearly outlined bulb I failed to detect.

These results in the main confirm and emphasise those already derived from the study of embryo and new-born rabbits. And they further show that the appearance of bulbs in the larynx is probably simultaneous with their development in the papillæ of the tongue, soft palate, and uvula. The existence of bulbs in the larynx of fœtuses and young children is denied by Kanthack[1]; but despite his surprising and somewhat sweeping assertions to the contrary, they are nevertheless present in the

[1] *Virchow's Archiv*, Bd. cxix. (1890), pp. 333, 334.

larynx of both.[1] I pass his first conclusion by without discussion (viz., "Wir schmeckensowohl an der Larynxschleimhaut wie auch an der Zunge an Theilen, wo diese Gebilde gänzlich fehlen," etc.), as he fails to mention the regions of the tongue and larynx which are endowed with the sense of taste, and yet are unsupplied with taste-bulbs. He mentions further finding similar formations in the mucous membrane of the inferior turbinated bone. He says:—"Wir finden sie hier in den Einsenkungen zwischen zwei Papillen, indem sich die Papillen von den Seiten herüberbengen und mit ihren Spitzen zusammentreffend einen 'knospenartigen' Raum einschliessen, der von den Zellen, welche die sich entgegensehenden Seiten der Papillen ausschmücken, innegehalten wird." This last discovery, he observes, suggested to him the explanation of the bulbs of the larynx, an explanation, certainly, which is sufficient to explain away the very existence of the bulbs themselves. I have no reason to question his finding "bud-like spaces" in the mucous membrane of the inferior turbinated bone; and I believe with him that these are precisely what he did find in his adult larynxes; but that he found any genuine bulbs I very much doubt, particularly as he himself admits that he has never observed them in the larynx of fœtuses or young children. This explanation of the nature of the bulbs of this region is, I think, wholly inadequate, and if for no other reason than that it is based upon a mistaken conception of their true nature. That the bulbs of the larynx are, as a rule, less highly organised than those of the tongue is quite true (though I have occasionally observed perfectly formed bulbs in the former region); but that they are morphologically identical I think there can be scarcely a shadow of doubt.

The important question raised by Kanthack in this connection, and which still awaits a satisfactory solution, is that of function. This I hope to discuss on another occasion.

[1] *Vide* paper by author, *Jour. Anat. Phys.*, vol. xxiii. (1889), pp. 572, 574.

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7. 6.

Fig. 7

Fig. 4.

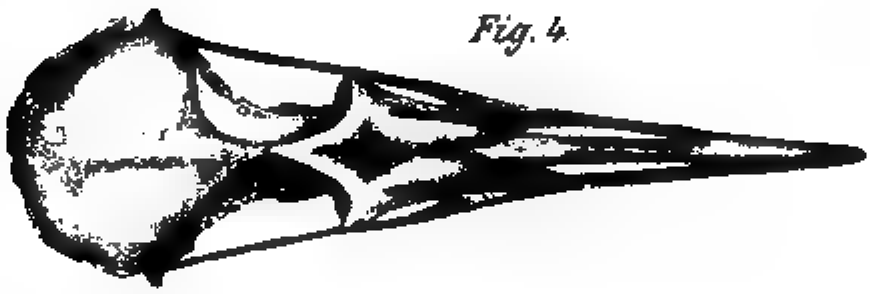
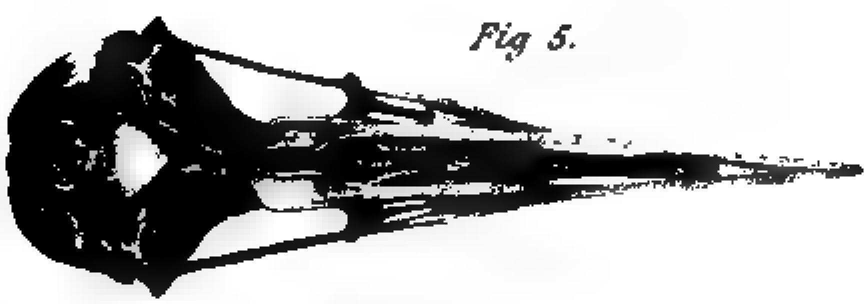


Fig. 5.



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ARCTIC & SUBARCTIC WATERBIRDS.

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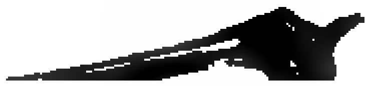
Fig. 9.



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ARCTIC & SUBARCTIC WATERBIRDS.

I will therefore confine myself to brief comparative notes upon the skeletons of a Gull, a Plover, an Oyster-catcher, and the Sheathbill, and while introducing a few other forms will strip the subject of all detailed discussions as much as possible. After the characters have been thus compared, I will briefly offer my conclusions upon the subject of the probable kinship of these forms, so far as is pointed out to us through a study of their several skeletons. With respect to the Gulls, I will introduce only such osteological characters as are typically larine, and present in the vast majority of that group; the same may be said for the Plovers.

Fortunately, the general osteological character of both of these latter groups have become perfectly familiar to us of late years, through numbers of papers that have been prompted by, and are the outcome of, the admirable presentation of cranial and other characters by Huxley in his important memoir on the "Classification of Birds" (*Proc. Zool. Soc.*, 1867), to which I may refer my readers.

Of the Skull.

(Plates XI. and XII., and others of previous Parts.)

Turning first to the osseous mandibles of the skull in *Chionis*, and more particularly that portion which during life is covered by the horny sheath of the beak, we are struck with the difference presented from the same part in a Gull, a Plover, or still more in an Oyster-catcher.

This anterior part of the osseous mandible in *Chionis* differs in no respect whatever from the corresponding structures in any Grouse or the Common Fowl. It is gallinaceous typically. But as we pass backwards over the skull, we first find the Fowls to be holorhinal birds; while *Chionis*, in common with the Plovers, Gulls, and Oyster-catchers, are schizorhinal types. However, in this connection we must remember that we find among the pigeons, and the intergrading *Columbidæ* and *Gallinæ* some of the best examples of schizorhinalism in the class.

Still keeping these gallinaceous types before us, it is a question as to how much significance we are to attach to the tuberous frontal region of the cranium in *Chionis*, or to the peculiar saddle of horn that surmounts its superior mandible in life.

Either of these may have arisen through the law of natural selection, as have very similar structures (sometimes aided by man's ingenuity) in the Horned Fowl.[1]

Two other gallinaceous characters are to be seen in our Sheathbill; the *lacrymal bones* are very much like what they are in the Fowls, agreeing with these elements as we find them in any Grouse of the first year, but lacking the peculiar descending spine-like processes of the adult birds; then both in *Chionis* and the Fowls, we find the aborted antorbital plates to be in the same case.

As for the vault of the skull, and the greater portion of its posterior aspect, particularly the supraoccipital region, it is all strongly gallinaceous in the Sheathbill, and strikes us at once upon the most superficial examination. The same may be said for the basi-temporal region, the pterygoids, and the rostrum; but the occipital condyle, the bony surroundings of the external auditory meatus, and the quadrates, are nearly as we find them in *Hæmatopus*.

The *maxillo-palatines* in *Chionis minor* are much like these bones as we find them in some of the Pigeons. Huxley says for the *Columbidæ* that "the maxillo-palatines are larger than in the ordinary gallinaceous birds, and are elongated from before backwards, and spongy in texture, not scroll-like."

In a specimen of *Zenaidura* before me, I find the maxillo-palatines *not* spongy but rather smooth, inflated, and elongated bodies, having the same relation with the surrounding bones that the maxillo-palatines in *Chionis* have.

The *palatines* and the *vomer* in the Sheathbill, both in their structure and relations, stand immediately between the Plovers and the Gulls. But we know the transition, particularly in the case of the palatines, to the Fowls is easy, and not far to go.

The *mesethmoid* in *Chionis* projects beyond the bases of its lateral wings: and in this it agrees with the *Charadriomorphæ* and not with the *Alectoromorphæ;* but in both groups the mesethmoid forms the greater part of the interorbital septum behind it.[2] In the fowls this septum is not always perforated by

[1] See Darwin, *Animals and Plants under Domestication*, vol. i. p. 320, fig. 36.

[2] This fact was noticed also by Dr Ant. Reichenow in his admirable paper "On the Osteology of *Chionis minor* and the position of the Genus in the System"

a fenestra (I have a large series of the skulls of the Alectoromorphæ before me), as it is nearly, I believe always so, in the Plovers, Oyster-catchers, Gulls, and Pigeons. At the side of the skull in *Chionis minor* the crotaphyte fossa agrees with the *Charadriomorphæ*, and the same may be said of its sphenotic and mastoid processes; but at the same time there is a wonderful likeness between these latter, and their appearance in a three-quarter grown Grouse.

There is still an exceedingly interesting feature to be found in the skull of *Chionis minor* left for our consideration, and these are the *supraorbital glandular depressions*, which are very deep and terminate in front in a single foramen on either side, just behind the massive frontal enlargement. Now these fossæ are altogether absent in the gallinaceous birds, feebly developed in many of the Gulls and Plovers, but strongly marked in *Hæmatopus*, some of the Auks, as *Alca* and *Uria*, and crop out in a strange way in such forms as *Himantopus*.[1]

Their form in *Chionis* agrees best with *Hæmatopus;* but in *Hæmatopus* the foramina are not entire, their lateral margins having given away, converting them into deep notches. If the frontal region in a skull of *Uria troile* were banked up a little, as it is in *Chionis minor*, then with the exception of some little difference in size, these depressions would be alike in the Auk and the Sheathbill. (Compare this character with the figures given in the Plates of the present Part, and those in the plates and figures of former Parts).

In regard to the *mandible*, I find the mandibular ends with their angular processes agreeing *entirely* with *Hæmatopus*, while beyond them the ramal sides and the symphysis stand immediately between the Plovers and the Fowls, the former claiming the greater share of resemblance behind, the latter predominating in the anterior moiety.

(*Jour. für Ornithologie*, 1876, p. 85). I must here express my sincere thanks to Dr L. Stejneger, of the Smithsonian Institution, for having not only copied this entire article for me, but for translating it as he did so into English, and thus bringing it under my eye when my long distance from home rendered the original not available.—R. W. S.

[1] See my papers upon the "Osteology of *Podasocys montanus* and the Osteology of *Numenius longirostris*, with Notes upon the Skeletons of other American Limicolæ," *Jour. Anat. and Phys.*, Oct. 1883 and Oct. 1884, for the forms in which this character is best marked among the *Charadriomorphæ*.

To recapitulate, then, we find the skull of *Chionis minor* to be a veritable columbo-gallinaceous one, having strongly impressed upon it other characters of some such form as *Hæmatopus*, with traces here and there, as we might expect, of larine structure.

If I had the skull alone to judge from, I should say that it was compounded of a Murre, an Oyster-catcher, and a Fowl—the last rather predominating in weight and importance of the characters, and I would add that I believe through it, and from its ancestral stock, the Pigeons get their maxillo-palatines and undoubtedly their schizorhinal structure.

Beyond all question, judging from this part of the skeleton alone, we must believe that *Chionis* is one of those surviving ancestral types, through the original stock of which all of these groups have been derived, and are now more or less nearly related.

Of the Vertebral Column and Ribs.

It would be a difficult matter to decide the question of the relationship of *Chionis minor*, had we but the vertebral column alone to rely upon. This arises from the fact that we have no single living form that presents all the characters of this part of the skeleton in itself, or even with certain due modifications and departures therefrom. This applies to the Plovers, the Pigeons, and the Fowls and their allies, for in none of them does the spinal column partake throughout of a class of characters comparable with those found in the vertebræ of *Chionis*. Aside from the question of the number of vertebræ in the spinal column, we often find the general aspect, or actual details sometimes, having a tendency either towards or from the corresponding parts of some of the types of the groups to which it is related. But here *Chionis* seems again to partake of them all.

One fancies that he sees in the skeleton of the neck of *Rissa* a decided inclination Ploverwards; but no such thought would arise in our minds from an examination of the cervical series of *Larus glaucus*. Yet the dorsal series of vertebræ in both of these forms are strictly those of a Gull. So we see it in many others of the class, and we see it again in the cervical vertebræ of the Oyster-catcher, where the bones present unquestionable characters, linking this bird with the *Laridæ*.

As to the *number of vertebræ*, present or absent, in any particular form, I do not think we are yet in possession of the requisite amount of this kind of information and data to judge of how much weight should be attached to that factor as a character. To properly decide upon the nearest group that such a form as *Chionis minor* is related, judging alone from the free vertebræ of its spinal column, or those extending from the skull to the sacrum, and its ribs, we should have before us these parts of the skeleton from a very large representation of the groups known to be more or less nearly allied. Then the corresponding vertebræ should be compared carefully through the entire series before any opinion could be arrived at worthy of our consideration. Until some such exhaustive data for the vertebral column is at hand, it is far better for us to rely, so far as the osteology goes, upon the characters offered in the skull, the shoulder girdle, sternum, and pelvis, and present with caution what we find or suspect in the vertebral column. This must yet a while be true of the limbs and much of the "soft parts" in the anatomy of the class.

It will be of interest to present here, however, in a tabulated form, the count I have made in a number of more or less nearly related species, together with *Chionis minor*, of the vertebræ in the skeleton of the neck.

Species.	The vertebra upon which the ribs are first liberated.	The first vertebra, which has its ribs connecting with the sternum by costal ribs.
Rissa tridactyla, . . .	Fourteenth, . .	Sixteenth.
Hæmatopus backmani, . .	Thirteenth, . .	Sixteenth.
Chionis minor, . . .	Fourteenth, . .	Sixteenth.
Œgialitis montanus, . .	Thirteenth, . .	Fifteenth.
Zenaidura macroura, . .	Thirteenth, . .	Fifteenth.
Centrocercus urophasianus, .	Fourteenth, . .	Sixteenth.

Now, without entering upon the details of all the comparisons I have carefully made between the vertebral column of *Chionis minor* on the one hand and the large number of Gulls, Plovers, and other forms on the other, I am compelled to agree with Dr Reichenow in his opinion, as set forth in the paper quoted above, that this part of the skeleton of *Chionis* resembles more the *Charadriomorphæ* than it does the *Cecomorphæ*, notwith-

standing the fact that we find in such a bird as *Hæmatopus* that the pleurapophyses of the thirteenth vertebra have become free ribs. The vertebral column of the two birds are very much alike in other respects; and I have specimens in my cabinet to show that even in the same species, sometimes, the above condition of things may occur.

Even Dr Reichenow seems to have secured both a specimen of a Plover and an Oyster-catcher that agreed with *Chionis minor* in this particular, for he writes that "the number of ribs is exactly the same [for *Chionis*] as in *Charadrius* [*pluvialis*] and *Hæmatopus*, while *Glareola* has one rib less" (page 88).

I find I have two complete skeletons of *H. backmani* before me, and in both there are three pairs of free ribs, followed by six pairs that connect with costal ribs and the sternum, and finally another pair where the costal ribs do not quite reach the sternum.

Turning to the two skeletons at hand of *C. minor*, I find that they both agree with this arrangement exactly, except, as I have already stated, they have one pair less of the anterior free ribs, or, in other words, the thirteenth vertebra of the column does not have its pleurapophyses liberated as movable riblets in the adult Sheathbill.

Of the Sternum and Pectoral Arch.

(Part I. Plate IV. fig. 23, and Part II. Plate III. fig. 13, to be compared with others).

It is not at all surprising that ornithotomists have been puzzled in regard to their choice of a sternum from among allied groups that most resembled the sternum of *Chionis minor*. A glance at the figures in Plate IV. Part I. will be sufficient to explain the reason for this, and point out how much these bones are alike in Gulls, Charadriomorphs, and the Sheathbill.

To represent the *Laridæ*, I have chosen the sternum of *L. delawarensis* as one presenting their characters in the best way: and the sternum of *Hæmatopus* certainly enters into the comparison.

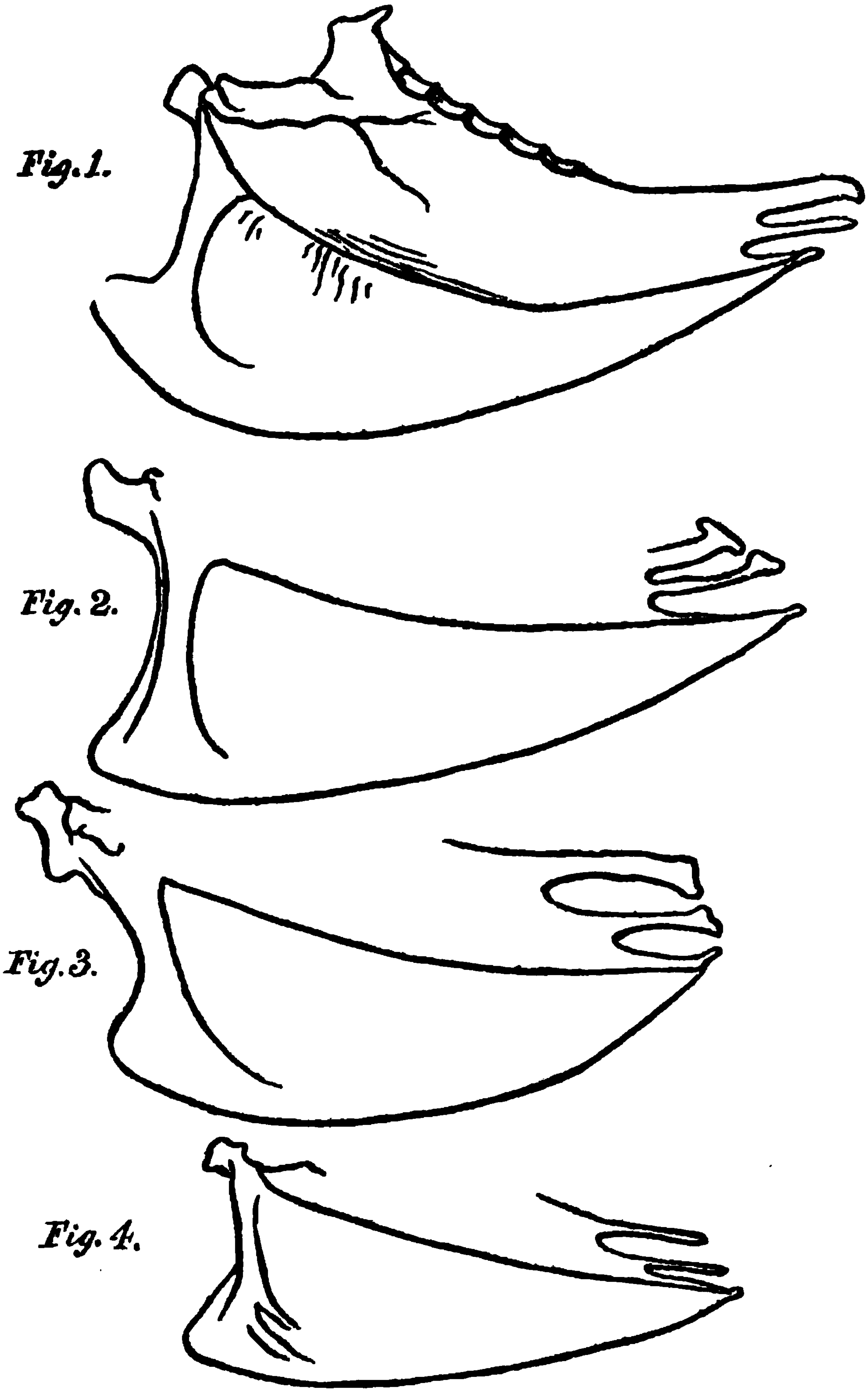
Now, I must dissent from the opinion arrived at by Dr Kidder after his examination of this bone, as well as disapprove

of the method adopted for comparing it, and the weight that has been attached to the various characters it presents.

The comparable points in a bird's sternum are (1) the general form of the sternal body; (2) the form, size, and position of the carina; (3) the condition and pattern of the xiphoidal extremity; (4) the costal borders; (5) the muscular lines upon the pectoral aspect; (6) the manubrium and coracoidal beds; and (7) the presence or absence of pneumaticity.

Taking these up in the order that I have given them, we find the general form of the sternal body in *L. delawarensis*, *Hæmatopus backmani*, and *Chionis minor* to be of an oblong figure, and in each its width equal to about half its length; it is concave above, and correspondingly convex on the pectoral aspect. The greatest amount of concavity is enjoyed on the part of *Larus*, the least by *Chionis;* the Oyster-catcher holding a middle place. (2) In all of these forms the anterior border of the carina is concave to the front, and slopes from the manubrium to the carinal angle. In *L. delawarensis*, as in all other Gulls, this angle is very prominent and somewhat curved upwards, and of a consequence the anterior border of the keel is unusually concave. This condition is so much altered in *Chionis* that, although the anterior border is concave, the whole is rather retreating. Here, again, we find the Oyster-catcher filling the middle place in standing immediately between these two extremes, as it does with the other characters presented on the part of the carina. (3) All these forms have a four-notched sternum, *i.e.*, a pair on either side of the keel, the notching being most profound in *Chionis*, next in *Hæmatopus*, and least in the Gulls. (4) The costal borders in all these species have six facets on either side, but the interhæmapophysial concavities are shallowest in *Chionis*, deeper in *Hæmatopus*, and still deeper in the Gulls, where they may even present pneumatic foramina,—a character never present in *Chionis*, nor in any Charadriomorph that I have ever examined. (5) The figures in the plates cited above show the position of the muscular lines on the pectoral aspect better than words can describe them; they are nearest the costal borders, or most external, in *Chionis;* approach nearer the keel in *Hæmatopus*, and hold a still nearer position in the Gulls. This, again, leaves the

Oyster-catcher in the middle. (6) The manubrium is largest and deepest in *Chionis*, being nearly of a size in the Gull and



Figs. 1-4.—Outlines and Partial Outlines of Sterna of various Birds for Comparison. Natural size; left lateral views. By the Author from the specimens.

Fig. 1. *Larus delawarensis* (Author's collection).
Fig. 2. *Hæmatopus backmani* (Smithsonian collection).
Fig. 3. *Chionis alba* (Kidder's type, Smithsonian collection).
Fig. 4. *Charadrius squatarola* (Specimen 7963, Smithsonian collection).

Oyster-catcher; in all, the caracoidal grooves meet in the median line at its base, their mid-convexities are nearly of a size in *Chionis* and *Hæmatopus*, to be found markedly smaller in the Gull. (7) The sternum of *Chionis minor* is non-pneumatic; this is also its condition in *Hæmatopus* and all the Plovers I have ever examined; in the *Laridæ* it is pneumatic.

The results of this examination go to prove that the sternum of *Hæmatopus* holds a middle place in points of resemblance between *Chionis* and *Larus*, and of a consequence the sternum of *Chionis* is more like the sternum of *Hæmatopus* than it is like the sternum of the *Laridæ*.

Applying a similar analysis to the characters presented by the elements of the *pectoral arch*, I find again that, in respect to the coracoid and scapula, that *Hæmatopus* holds the middle place between *Chionis* and the Gulls; but, in the case of the furcula, the bone in *Chionis* and *Hæmatopus* are, except in the point of size, the counterparts of each other, while a great departure is made from them by the Gulls, in the latter having on the outer aspects of the clavicular heads the promontories to support the projecting facets for articulation with the coracoidal heads, an arrangement they hold in common with the *Alcidæ*, and are carried to perfection in such forms as *Sula bassana* (see figures).

Of the Pelvis.

(Compare the figures in Plates IV. and V. Part II.)

Little doubt will remain in our minds, I think, after a comparison of the drawings that are contained in Plates IV. and V., as to the pelvis this bone in *Chionis minor* most nearly resembles. Here we find the pelvis of the the Sheathbill, the Oyster-catcher, an Auk, and of the Ring-billed Gull, the last having been chosen as it seemed to represent the majority of the characters of this part of the skeleton as they exist in the *Laridæ*. In Plate IV. the likeness from the dorsal view, between the pelvis of *Chionis* and *Hæmatopus*, and between those of *Alca* and *Larus*, strike us at once, and of course this is equally true for the lateral views given in the following plate. The general form of the pelvis of *Chionis* agrees exactly with that bone as found in *Hæmatopus*; indeed it would be hard for

us to single out any particular character worthy of consideration in which they essentially differ. *Chionis* has its post-pubic elements prolonged, and curving towards each other behind, but I take this to be more of a gallinaceous trait than anything it has to do with the Laridæ (compare with figure of Fowl's pelvis in Plate II.).

This, I think, will be evident if the pelvis is compared with my drawing of that bone from a specimen of *Canace canadensis* in the "Osteology of the N. A. Tetraonidæ."[1]

Aside from this general resemblance in form, however, the best characters for comparison are to be found upon the ventral side of the bone.

Here we find in the Gulls the leading vertebra that anchyloses with the pelvic sacrum (*dorso-lumbar*) stands out beyond the anterior margins of the iliac bones. This, I believe, to be invariably the case in the *Laridæ.* In *Chionis* and the Oyster-catcher, however, this is not the case, their first sacral vertebra being beneath the ilia and more or less free. Next, we find in this group that that vertebra of the sacrum which is opposite the acetabulum sends out strong apophysial abutments to meet a ridge, on either side, developed by the internal iliac walls, just posterior to the acetabula. Sometimes these apophysial extremities meet the ilia below these cotyloid cavities (*Rissa*), but the struts are *always single.*

Now, in both *Chionis* and *Hæmatopus, two* consecutive vertebræ lend their apophysial projections to form these braces, and they are thrown out against the internal iliac margins, rather than their walls, particularly in *Chionis,*—a slight encroachment being made upon this wall in the Oyster-catcher.

Finally, in both these birds the hinder iliac margins grasp the first free caudal vertebra with sufficient firmness to prevent its movement, and in detaching the skeleton of the tail in the dried specimen this vertebra naturally remains with the pelvis, unless special pains are taken to bring it away with the rest. No such condition as this is to be found in the *Laridæ* so far as I have examined their skeletons.

It ought to be mentioned that the propubis is developed in all these birds to some extent, very slightly to be sure and not

[1] Hayden's *Twelfth Ann.*, pl. xiii. fig. 90.

so well marked, as it is, even in those gallinaceous birds where it is the least pronounced.

Again, on lateral view we are to notice the notch that stands between the ilium and ischium, in their posterior margins. This feature, I believe, is never present in the Fowls, though it is to be seen in *Tinamus*. It is the remains of the far greater interval that originally existed between the ilium and ischium in reptiles, and is best marked in birds that occupy the lower planes in the scale of organisation.

The pelvis of *Chionis minor* then is far more like the pelvis of *Hæmatopus* than it is like the pelvis of the *Laridæ*. I am not at all surprised at the fact that M. de Blainville recognised this striking resemblance between these bones in the Oyster-catcher and Sheathbill when he came to compare their skeletons.

The Appendicular Skeleton of a Gull, an Oyster-catcher, and the Sheathbill.

(Compare the numerous figures of the long bones of Gulls, Auks, the present bird, and others, given in the text and plates throughout this series of memoirs from Parts I. to IX.)

The necessary comparisons to be made for this part of the skeleton will not detain us long, for it is not my intention to enter upon long tedious details and descriptions of all the bones in the upper and lower extremities of these several forms, but rather tersely present the differences I have found to exist, after a most exhaustive examination of the limbs of the three types we have under consideration.

With respect to the *pectoral limb* we find that in *L. delawarensis*, *Chionis*, and *Hæmatopus*, it is in all non-pneumatic, though the shafts of the long bones present the usual medullary cavities.

In the *humerus* we find the distal extremity alike in *Chionis* and *H. backmani* in all particulars, while in *L. delawarensis*, there is seen that distinctive fossa next to the pseudo-pneumatic fossa, which becomes so very striking in other *Laridæ* (*Rissa*). It amounts to almost *nil* in the other two birds. In Gulls the humeral shaft is nearly straight, while both *H. backmani* and *Chionis minor* show the usual sigmoid curves.

The distal extremities are alike in *Chionis minor* and *H. backmani*, while in the Gull we find that extraordinary fossa on the palmar side of the bone just above the radial and ulnar tubercles. It is so thin at its base in some Gulls as almost to create a fenestra in this part of the shaft (*L. glaucus* and Oyster-catcher). This is entirely absent in the Sheathbill. All have the "ectocondyloid process" strongly developed.

The bones of the antibrachium, as we would naturally expect after what has just been said in the foregoing paragraphs, are more alike in *C. minor* and *H. backmani* than either of them resemble the Gull, though the differences among the three are not nearly so striking here as we find them in the humerus, and it would be difficult to distinctly specify exactly what they are. Moreover, as I make these comparisons, I have before me the limbs of a number of Gulls, and it is my intention to differentiate only such characters for comparison with the other two birds as will hold good for the *Laridæ* at large.

All three forms have the two usual segments in the carpus. What we have said in regard to the bones of the antibrachium, applies with equal truth to the *carpo-metacarpus*, though in general form and appearance the bones are more alike in *C. minor* and *H. backmani* than either resemble the *Laridæ*.

I find the pollex digit bears an additional diminution joint at its extremity in both the Sheathbill and the Oyster-catcher —such a bone is never found in the skeleton of *L. delawarensis*. It is found in several of the Parrot Auks.

The proximal phalanx of the index digit offers us an excellent character for comparison, and one that is constant for the forms we have in hand.

Its posterior expansion in the *Laridæ always* exhibits two large fenestræ, while this portion is entire and very thick in *Chionis minor* and *Hæmatopus backmani*. The remaining digits are more alike in the last two mentioned birds than either resemble the Gulls.

Except in point of size, then, the skeleton of the pectoral limb is most alike in *C. minor* and *H. backmani*, and in both it differs in several important characters from the pectoral limb of the *Laridæ*.

Of the Pelvic Limb.

As in the case with the upper extremity this limb is entirely non-pneumatic in the forms under consideration.

In comparing the several femora we find the trochanterian ridge much better developed in *C. minor* and *H. backmani* than it ever is in any of the *Laridæ.*

The shafts of these bones are all nearly straight and sub-cylindrical. Their distal extremities show some differences, the Oyster-catcher having the condyles of an unusual size in comparison with the remainder of the bone.

In the *Laridæ* we have a *patella* always present; this sesamoid is not developed in either *H. backmani* nor *Chionis minor.*

With respect to the bones of the leg, I can say that after careful comparison I find both the tibio-tarsus and fibula of *H. backmani* and the Sheathbill much more alike than either resemble these bones in any of the Gulls. It is fortunate for those who see the larine affinity in the skeleton of *Chionis minor,* that I chose the leg-bones of the ring-billed Gull for my comparison, for I could have taken them from other *Laridæ,* where the differences would have been far more striking. The introduction of the patella in the case of the Gull would also have enhanced the dissimilitude to some extent. The general resemblance between the tarso-metatarsus of the Oyster-catcher and that of the Sheathbill is at once apparent, and this likeness is extended throughout the anterior toes. But in the Oyster-catcher we have no hind toe present, though at the site of the accessory metatarsal there is a lamellar process anchylosed to the shaft of the bone.

Simply the presence or absence of the hind toe, however, has nothing whatever to do with the general resemblance of the skeletons of these two birds. According to Dr Reichenow the skeleton in the Glareole very much resembles the skeleton of *Chionis,* the resemblance being much nearer than it is to any of the Gulls; and the *Glareolidæ* have four toes. Again, *Rissa* has nearly lost a hind toe, and many of the Plovers have but three, and the hallux is wanting in the *Alcidæ.*

The fundamental characters of the pelvic limb of *Chionis minor* are more like those of *Hæmatopus* than they are like those of any of the *Laridæ.*

In November 1885 I received from Dr Thomas H. Streets, U.S. Navy, a very excellent skeleton of *Aphriza virgata*, he having kindly collected it for me in Alaska. It is my intention some day to endeavour to show the relations this interesting bird has with the Oyster-catchers, the Turnstones, and such forms generally, so far as the characters of its skeleton seem to indicate. At present I have not at hand any Turnstones,[1] but have been promised them from various quarters. They will be important forms, of course, for comparison with this Surf Bird. A casual examination of this skeleton of *Aphriza* inclines me to believe that its affinities with *Hæmatopus* will be found to be closer than they are with *Arenaria*.

Its skull looks like a miniature Oyster-catcher's skull, with the angularity of the latter toned down by a fair admixture of Sandpiper characters, these birds, as we know, having a smoother pattern of skull than we see in *Hæmatopus*.

Its sternum, likewise exhibiting characters about equally favouring the Plovers, Oyster-catchers, and the Sandpipers, has two notches in its xiphoidal extremity, on either side of the keel.

In my "Osteology of *Numenius longirostris*," &c. (*Jour. of Anatomy*, October 1884, p. 76), I made the statement, after examining a great many American types of Plovers and Sandpipers, that the only bird I had found among them with a one-notched sternum was *Gallinago delicata*. Since then I have collected at Fort Wingate, New Mexico (July 1885), a specimen of *Totanus solitarius*, that stands in the same case with *Gallinago* in this respect, it having but one large notch on either side of the carina of its sternum[2] (see "The Auk," this *Journal*, July 1888).

The pelvis of *Aphriza* reminds me more of that bone as generally seen among the larger and stronger types of Plovers

[1] Since the above was written, Dr T. H. Streets, of the U.S. Navy, has very kindly presented me with a fiue series of skeletons of this bird, representing both sexes; and at the present writing I have at my command all the necessary material to make an exhaustive osteological comparison of *Aphriza*. [This work has now been published: see my memoir "On the Affinities of *Aphriza virgata*," *Jour. Morph.*, vol. ii., No. 2, Boston, November 1888, pp. 311–340, pl. xxv. R.W.S.]

[2] The Woodcock and probably some few other limicoline birds also possess this character.

than any of the other forms referred to above, though here, too, we discover traces of the Oyster-catcher.

As I say, however, I am not fully prepared to offer a final opinion upon the affinities of *Aphriza virgata* : but I may be permitted to predict, however, that its pluvialine characters will predominate over any that it may possess connecting it with the Sandpipers, and that its hæmatopodine characters will probably, to an equal extent, prevail over any that it may claim connecting it with the Turnstones.

Conclusions.

In the several Parts of this series of memoirs I have already pointed out what I consider to be some of the affinities of the Pygopodes, Alcæ, Longipennes, and others, so that it will not be necessary in the present connection to recapitulate these views here. The kinship of the great Limicoline group with some of these is becoming more clearly defined for us every year that goes by, and as the structure of the many interrelated forms becomes better known. Another series leading away from these is seen in the Pigeons and Fowls—forms that imperceptibly merge into each other.

Now, such an organisation as we find in *Chionis minor* probably constitutes one of the links among the Plovers and the Gulls, standing close up to the former and having its nearest living allies in *Hæmatopus*, and such forms as *Glareola*. Recognising this as we do, we cannot ignore, on the other hand, the impress it has at least received upon its skeleton from the columbo-gallinaceous group; and the Bustards, through the Plovers, seem to offer us a partial clue here, or missing links in the line through *Hemipodius*, or perhaps, too, in some yet unknown way, through *Syrrhaptes*, the other connecting forms having passed away, and left us only such conjectures as these to offer upon the position of *Chionis* in the system.[1]

[1] As this paper goes to press, I would beg leave to state that since it was written, some five or six years ago, Professor Max Fürbringer's princely work *Untersuchungen zur Morphologie und Systematik der Vögel* has appeared, and those two sumptuous volumes are now before me, the gift of their distinguished author. His views upon the systematic position of *Chionis* and related forms will have to be noticed by me later, in a work I now have in course of preparation.

EXPLANATION OF PLATES XI., XII.

Plate XI.

Fig. 1. Skull of *Chionis minor*, right lateral view; natural size.

Fig. 2. Skull of *Chionis minor*, superior view; mandible removed; natural size; figs. 1 and 2, by the author, from R. Kidder's type specimen.

Fig. 3. Skull of *Larus philadelphia*, right lateral view; natural size.

Fig. 4. Skull of *Larus philadelphia*, superior view; mandible removed; natural size.

Fig. 5. Skull of *Larus philadelphia*, basal view; natural size; figs. 3, 4, and 5, all from the same specimen by the author, from a specimen in his own collection, collected by Mr H. W. Henshaw at Washington, D.C.

Fig. 6. Pelvis of *Charadrius dominicus*, right lateral view; natural size; by the author (specimen 16,715 of the collection of the Smithsonian Institution).

Fig. 7. Pygostyle and last caudal vertebra of *Charadrius dominicus*, right lateral view; natural size (same specimen as fig. 6); by the author.

Fig. 8. Left humerus of *Urinator lumme*, radial aspect; natural size; by the author, from specimen 16,628 of the collection in the Smithsonian Institution.

Plate XII.

Fig. 9. Mandible of *Chionis minor*, superior aspect; natural size (Kidder's type specimen).

Fig. 10. Right metacarpus, with its pollex phalanx and ungual digit of *Urinator lumme*, anconal aspect; natural size (specimen 16,628 Smithsonian Collection).

Fig. 11. Right metacarpus, with its pollex phalanx of *Larus delawarensis*, anconal aspect; natural size; by the author, from a specimen in his own collection.

Fig. 12. Basal view of palatines, pterygoids, left quadrate, maxillaries, vomer, maxillo-palatines, and premaxillary of *Chionis minor*; natural size (Kidder's type specimen).

Fig. 13. Pelvis of common fowl, superior view (after Huxley).

Fig. 14. Pelvis of common fowl, left lateral view; same bone as shown in fig. 13.

Fig. 15. Sternum of *Urinator lumme*, right lateral view: natural size (specimen 16,628 of the Smithsonian Collection). All the drawings in this Plate were made by the author.

VARIABILITY IN THE LEVEL OF ATTACHMENT OF THE LOWER LIMB TO THE VERTEBRAL AXIS IN MAN. By AMBROSE BIRMINGHAM, M.B., *Professor of Anatomy, Catholic University, Dublin.*

GOODSIR says, in his "Memoir on the Constitution of Limbs,"[1] that "the nervous elements of the limbs appear, as in other parts of the vertebrate animal, to indicate most distinctly the morphological constitution of the sclerous elements."

This doctrine will, I think, be pretty generally accepted as correct; it may be that the nervous system is not in every case an absolutely reliable guide to homology, still it will be admitted that there is no other guide so reliable, no other system in the body so constant in its condition and so fixed in its position.

Nerves are clearly segmented at an early date, when all the body may be said to be in a state of segmentation; after a time changes take place, and the segmentation is obscured; still the nerves retain their segmental character in the adult when it has been largely lost in other parts. Consequently, as these nerves are definitely associated with the segments of the body, or somatomes, in the embryo we may adopt them as the keys to the morphology of parts which have become massed together in the adult, or which have had their primitive characters otherwise changed.

Again, when anomalous arrangements are found in parts where nerves and other systems are associated, even though the latter still present an appearance of segmentation, we must look to the nerves as affording the true reading of the condition present, in view of their superior constancy, and in view of the fact that the nervous system is the first to appear, is that one around which the other systems are built up, and that it probably affords the guiding lines along which the other structures are laid down in the development of the limbs.

If we admit then the value of the nerves, particularly of the

[1] *Edin. Phil. Jour.*, Jan. 1857, *and Anat. Memoirs*, vol. ii., 1868.

segmental nerves, such as the spinal trunks, in determining the value of parts amongst which they lie, we will the more readily admit their ability to determine the true position of the segments of the vertebral column, between which they, as spinal nerves, are placed. In considering the connection existing between these parts, it is well to remember that the nerves are formed first, the vertebræ afterwards, and that the segmentation of the nerves is primary, whereas the segmentation of the vertebræ is secondary, and quite different from the first division of the part which subsequently becomes the vertebral column. In the primary division the central mesoblast is converted into proto-vertebral somites, with a special nerve to each somite; subsequently a new division of the mass takes place with the production of vertebræ, the lines of segmentation lying this time not between the nerves but opposite to them.

A certain number of these segmental spinal nerves pass into each limb; the corresponding somites or body-segments are also usually considered to pass into and take part in the formation of the limb. In the differentiation of parts which follows, almost all traces of segmentation disappear, except in the case of the nerves; the other parts form new connections, and we must look to the nerves rather than to skeletal structures if we are to determine correctly the segments from which the limb has been formed.

In an able paper on the "Position of the Mammalian Limb,"[1] Professor A. M. Paterson gives the results of an examination of the limbs of a number of animals, undertaken with the object of determining the variations of the level at which the limbs are primarily developed from the central axis; in other words, to determine whether the limbs are developed from the same or from varying segments in different animals. Recognising that the bony connections of limbs may change considerably during development, or that the limbs may after a time become applied to axial segments which do not correspond to those from which they have been developed, he adopts the more reliable guide afforded by the nerves, which cannot shift their positions along the axis after they have grown into the limbs. In the case of the hind limb, the posterior limit of the limb plexus can fortu-

[1] *Jour. of Anat. and Physiol.*, vol. xxiii. p. 283.

nately be easily recognised; the last nerve which goes to the limb is the 3rd sacral of human anatomy, or the *nervus bigeminus*, which divides into two parts, one going to the pudic, the other to complete posteriorly the lumbo-sacral plexus. It indicates the last segment which takes part in the formation of the limb, and by observing its numerical position in the spinal series, the wandering of the limb headwards or tailwards may be recognised.

In this way Paterson found that the hind limb in mammals is inconstant in position: in some it shifts headwards, in others towards the tail.

In the *Morphologisches Jahrbuch* for 1876, Rosenberg, from his researches on the development of the vertebral column, puts forward a view that in man the column is undergoing a gradual process of shortening. The ancestral form of vertebral column, he considers, had twenty-five movable vertebræ anterior to the sacrum; in the present form there are twenty-four, but the column of the future shall have twenty-three. He also points out that there is to be found connected with the transverse process of the first lumbar vertebræ of the fœtus a cartilaginous rudiment of a rib, which subsequently disappears through its fusion with the transverse process. This suggests that in the ancestral type there were twenty-five movable vertebræ in front of the sacrum and thirteen ribs, a condition similar to that most frequently found in the Gibbon. The question arises, Do we ever find this suggested ancestral type in man at the present day? I think the answer must be—Yes.

Within one year I found amongst not more than fifty subjects two in which there were twenty-five movable vertebræ anterior to the sacrum, or, putting it into terms of human anatomy, in which there were apparently six lumbar vertebræ. This proportion I must consider abnormal. I have looked upon it as a coincidence; still, I believe, if the condition be sought for, it will be found to exist more frequently than is expected.

The first of these specimens I examined with considerable care, and I give an account of it at some length. The other specimen agreed with it in all important details; the trifling differences will be mentioned afterwards.

First, as to the number of vertebræ in the different regions of

the column. In the coccyx there were but three vertebræ, all freely movable upon one another and upon the sacrum. The last piece was somewhat constricted in the middle, but this is a common condition of the last piece of the coccyx. The middle piece resembled an ordinary 3rd coccygeal vertebra. The first in appearance was something between an ordinary first and second piece, but resembled more closely the second; its cornua were ill developed, and did not meet those of the sacrum, and its transverse processes were rudimentary.

The sacrum was composed of five pieces united together, and was apparently in every respect a typical normal sacrum; the ilium articulated with its first three segments, with the third not so fully as is commonly the case; still the connection was as extensive as that which I have found on many normal specimens, and its existence was unequivocal. The last piece differed in no respect from what we habitually know as the 5th segment of the sacrum; it was firmly and completely fused with the rest of the bone.

There were six lumbar vertebræ. The first resembled in general appearance, as is ordinarily the case, the last dorsal, with the differences produced by absence of facets for ribs, and direction of articular surfaces, &c.; but, in addition, the transverse process of the left side carried two accessory nodules of bone connected to it by two separate synovial articulations surrounded by capsules. Each of these nodules was about as large as a good-sized pisiform bone; one was articulated to the very tip of the transverse process, the other to its back, quite close to the first; the process itself was short. The transverse process of the opposite side presented no peculiarity. There was a considerable lateral curvature in this region of the spine, the convexity of which was directed to the left.

Unfortunately the head and neck had been removed before my attention was called to the condition of the subject; consequently my observations upon the number of cervical and dorsal vertebræ were made under difficulties. So far as I could make out by an examination of the bones, the cervical and thoracic vertebræ were normal in number, but the condition of the nerves removes this conclusion from the region of doubt.

In the nerve relations I felt that the chief interest of the

specimen lay, and in them I expected to find the key to the nature of the additional segment in the lumbar column. In this, I think, I was not disappointed.

The cord ended opposite the upper part of the body of the second lumbar vertebra—a level which may be considered normal.

As to the nerves. The last dorsal was present in its usual position, running along the lower border of the last rib. Each lumbar vertebra had a nerve passing out beneath it; there were thus six lumbar nerves. Of these the upper four formed a normal lumbar plexus, giving off all the branches usually found coming from that plexus; but below this the arrangement was peculiar. Instead of the ordinary condition (4th sending a branch to 5th to form lumbo-sacral cord, this passing over brim of pelvis and joining with 1st, 2nd, and greater part of 3rd sacral to form great sciatic), in this case a small part of the 4th lumbar joined *the whole of the 5th and 6th*, forming a large cord —like the lumbo-sacral—which, after passing over the brim of the pelvis, joined the 1st and *part of* the 2nd sacral, and formed the great sciatic. The remaining part of the 2nd sacral joined a portion of the 3rd, producing the internal pudic nerve. The 4th and 5th sacral were present, but there was no coccygeal; in other words, the last nerve given off by the cord made its exit opposite the junction of the sacrum and coccyx, not beneath the first piece of the coccyx, as is customary.

In the normal subject the 28th spinal nerve, which comes out through the 3rd sacral foramen, and divides into two parts—one going to the great sciatic, one to the internal pudic—is known as the 3rd sacral, or *nervus bigeminus*, and it is considered to be the last nerve which enters into the formation of the lower limb plexus. Its position is constant in the series of spinal nerves; in man it is always the 28th—at least, I have never met any variety in this regard. Another definite and fixed nerve is the last spinal nerve; it is always, I believe, the 31st in the series. So we may speak of the nervus bigeminus and the last spinal nerve as two landmarks—two definite and constant points, the former normally found beneath the 3rd sacral segment, and the latter beneath the first piece of the coccyx. Putting this conversely, the vertebra beneath which the nervus bigeminus comes

out is the true 3rd sacral, and that beneath which the last nerve comes forward is the 1st coccygeal vertebra.

This was the condition of parts found upon dissection. There immediately arises the question, Where has this additional lumbar vertebra come from? The reply must be that it is due either to the interpolation of a supernumerary segment in the lumbar region, or to the conversion of a dorsal on the one hand, or of a sacral on the other, into a lumbar vertebra. Which of these two explanations is correct the nerve relations can best decide.

If the abnormal number of lumbar vertebræ arose from the interpolation of a new segment, we should find, remembering the constancy of the nerves and the secondary segmentation of the vertebræ, but five lumbar nerves related to the six lumbar vertebræ, for the interpolated segment would have no corresponding nerve. Lower down, the relations of the nerves to the sacrum should be those normally found—the nervus bigeminus should come through the 3rd sacral foramen as usual, and the last nerve should pass forwards below the level of the first piece of the coccyx. But these were not the relations which obtained in this case; each lumbar vertebra had a nerve beneath it, the nervus bigeminus came through the 2nd sacral foramen, and the last nerve ran forwards between the sacrum and coccyx. So the connections of the nerves show quite clearly that the abnormal number is not the result of an interpolation, and they point just as clearly to the conclusion that it is due to an extension of the lumbar into one of the neighbouring regions; that is, to a conversion of either the 12th dorsal or the 1st sacral into a lumbar vertebra. Which of these two undergoes the conversion it remains to be decided.

If it were the 12th dorsal which had been transformed, the changes which we should find would be the failure of the now last dorsal—really the 11th dorsal—nerve to help in the formation of the lumbar plexus, and, connected with this, the *apparent* shifting of the plexus one segment backwards, the 2nd, 3rd, 4th, and 5th lumbar nerves forming it. The nervus bigeminus and the coccygeal nerve should retain their normal relations. The dissection showed not one of these

conditions present. So by a system of exclusion we arrive at the result that the additional lumbar vertebra was due to the conversion of the 1st sacral into a lumbar vertebra, owing to the shifting of the sacrum one segment tailwards. And we have positive proof that this is the true reading of the condition.

As we have seen, the nervus bigeminus comes normally through the 3rd sacral foramen, and the vertebra beneath which this nerve appears is always the true 3rd sacral; in like fashion the vertebra, beneath which the last nerve comes, is always the true 1st coccygeal. In the case which I describe, the nervus bigeminus came through the 2nd sacral foramen, therefore the vertebra beneath which it appeared is the true 3rd sacral, although it is the second piece of this sacrum, and the first piece of this sacrum is really the 2nd sacral segment, and going one stage further, the 6th lumbar is the true 1st sacral vertebra—the sacrum has begun one segment further back than normal. The sacrum contained five pieces, the last nerve appeared between it and the coccyx, but the coccygeal nerve comes forwards beneath the first piece of the coccyx, therefore the last piece of this sacrum is really the 1st coccygeal vertebra; this also shows us that the sacrum lies one segment further back than usual. This conclusion is slightly strengthened by the fact that the coccyx was composed of three pieces.

Then I think there can be little doubt that the presence of the additional lumbar vertebra was due to the fact that the sacrum had shifted its position one segment backwards. Or, since the sacrum is but a number of vertebræ modified and consolidated for the support and attachment of the pelvic girdle, we may put it that the increased number of vertebræ in the lumbar region depended upon the connection of the pelvic girdle to the vertebral column, one vertebra further back than normal.

The second specimen in which I found six lumbar vertebræ differed from that which I have just described in the following minor points:—1st, the coccyx was composed, as in the first case, of three segments, but the last two were here united immovably; 2nd, two well-developed lumbar ribs, each about

an inch and a quarter in length, were found connected by the head to the side of the pedicle by a small synovial joint, and by its neck to the front of the transverse process by fibrous tissue; 3rd, the whole vertebral column was fortunately obtained complete, consequently the number of vertebræ in each region was easily made out; the numbers in the dorsal and cervical region were normal; the lumbar had six vertebræ, but the lateral curvature observed in the first specimen was absent. The sacrum corresponded in general detail to that described above, but the ilium articulated more fully with the 3rd sacral vertebræ; indeed, the sacro-iliac articulation might be described as being perfectly normal.

With the exception of these points, the description given of the first specimen will apply exactly to the second also.

Here, then, we have the ancestral form of vertebral column of Rosenberg, and, adopting his view, we would consider it a reversion to an early type. But before going further we might perhaps turn our attention to the transverse process of the 1st lumbar vertebra. It will be remembered that in each specimen a lumbar rib was present connected to that process. In the first it was present only on one side, and it took the form of two separate nodules; in the other specimen well-developed lumbar ribs were present on both sides, connected to the transverse process and to the side of the pedicle, like an ordinary 12th rib. These facts are extremely suggestive, taken in connection with Rosenberg's statement that there is a cartilaginous representative of a rib present in this position in the embryo, which afterwards disappears by fusing with the transverse process. Before I read of Rosenberg's work I came to the conclusion, from a consideration of the above cases, that such a rudiment of a rib was present in the 1st lumbar transverse process, and that under certain circumstances this rudiment might show itself in its separate and complete form. If we adopt Rosenberg's view it would appear that it is suppressed owing to the advance of the sacrum and lower limb towards the thorax; and conversely, when we find a body in which the sacrum recedes to its former position, this rudiment returns to its pristine separate condition, thus reproducing the number not only of these vertebræ, but also of ribs found in the Gibbon amongst anthropoid apes.

We may even be tempted to speculate and to offer an opinion that when Rosenberg's future form of column, with only twenty-three movable vertebræ in front of the sacrum, is attained, the 12th rib will take its departure and retire into the condition of a cartilaginous rudiment, present as a separate structure in the embryo only.

In conclusion, while I have met with no specimen illustrating the type of vertebral column of the future as described by Rosenberg, I think the two cases which I have detailed above show clearly that a condition similar to his ancestral type does occur in man, and this occurrence, which may be considered a reversion to an early type, is a strong argument in favour of the theory which he has advanced.

OBSERVATIONS ON THE URINARY BLADDER AND URETHRA.

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WHILE conducting some physiological experiments on dogs, with the view to the study, first, of the mechanism, both nervous and muscular, of the natural retention and expulsion of urine and, secondly, of the function of each nerve going to the bladder and urethra, I soon became convinced that no satisfactory progress could be made unless an investigation into the anatomy of the muscular wall of the bladder and urethra and of the nerves of each were undertaken as a preliminary step to these experiments. Such a preliminary investigation was indeed necessary, because of the discrepancies and want of uniformity that exist concerning these parts in the various descriptive text-books of anatomy. Accordingly, I began the investigation in the human subject, but soon found that difficulties arose which could only be cleared up by examining the same parts in the lower animals. I, therefore, have supplemented my studies in the human subject by those derived from many of the lower animals, but chiefly from the domesticated ones. I propose to confine myself in this, the first part of my paper, chiefly to the anatomy of the muscular apparatus of the bladder and urethra.

The Urinary Bladder.

Before proceeding to refer to the more recent observations on the anatomy of the urinary bladder, it may perhaps be of interest to review in brief the history of the study of the anatomy of this organ. In doing this I shall do little more than make use of extracts from the works of such anatomists as seem worthy of note.

The urinary bladder received a certain amount of attention even in the earliest times in the history of scientific medicine. But so far as I have been able to gather from various old anatomical works, no observation of any importance seems to have been made on the

anatomy of this part of the urinary apparatus before that by Galen. In Laut's *l'Histoire de l'Anatomie* the following account of Galen's description of the urinary bladder is given :—

"L'Urine descend par les uretères, formés par une seule tunique, plus forte que la tunique des Veines et plus forte aussi que la vessie urinaire, mais plus foible que la vesicule du fiel.

"La vessie, que reçoit l'urine des uretères est formée par une membrane dont les fibres sont longitudinales, transverses et obliques, parce que la vessie attire, excrète et retient.

"L'uretre fèminin est court ; mais celui de l'homme est grand, fléche en S romain, et il faut une portion de la verge. L'origine de l'urètere est entourée en sortant de la vessie par une musclé sphincter."

Thus, Galen conceived of the urinary bladder as composed of a single membranous tunic made up of longitudinal, transverse, and oblique fibres, and having around its neck a sphincter presumably to prevent the constant escape of the urine. As no progress of any significance was made in anatomical science for centuries after this, we may at once proceed to the account given in the earliest English text-book of anatomy, written by Thomas Vicary,[1] who was senior surgeon to St Bartholomew's Hospital, and on several occasions the President of the Company of Barber-Surgeons. The following extract may serve to show his knowledge, and presumably that of his contemporaries, of the anatomy of these parts.

"The first thing that cometh in sight [in the pelvis] is the Bladder, the which is an official member compound of two nervous Pannicles, in complexion colde and dry, whose neck is carnous and hath muscles to witholde and let go. . . . . . The form of it is rounde; the quantitie is a pitcherfull ; in some more ; in some less," etc.

In this description one recognises an attempt to subdivide the single membranous tunic, as described by Galen, into two layers or pannicles ; the neck of the bladder "hath now muscles to witholde and to let go" urine ; and the capacity is noted as being variable. This means, so far as I can gather, variable as regards capacity in different persons, and not in one and the same person. What was Vicary's conception of the mechanism of micturition is difficult to imagine, as he gives no clue as to the manner of working of the bladder, except this much, that it possessed muscles around its neck to "*witholde* and *let go*" urine. The arrangement of fibres in the wall of the bladder, as described by Galen, is lost sight of, to be again discovered by a later anatomist.

In less than half a century after Vicary, a new interest arose in connection with this organ, as indeed in the whole field of anatomical science, when Vesalius published his great work on anatomy, and in which the bladder was thus described. The wall of the bladder is said to be composed of longitudinal, transverse, and oblique fibres, and the bladder to vary in its capacity ; the latter I take to mean variation in capacity in one and the same person. The former is, as has been above mentioned, merely a re-discovery of what Galen

[1] "Anatomie of the Bodie of Man," *Early Eng. Text Soc.*

had observed and described. This seems to have been the first attempt since Galen at describing somewhat minutely the structure of the wall of the urinary bladder; and it is a decided advance on what was taught by Thomas Vicary, inasmuch as the latter only conceived of two nervous pannicles or tunics forming the wall of a bladder that varied in size in different persons. The following quotation may serve to indicate the new doctrine as taught by Vesalius :—

"Vesicam implicantes fibræ, eadem, qua fibræ Ventriculi, et bilis vesiculæ, collocantur serie. Rectæ enim intimæ sunt, extimæ transversæ mediæ vero obliqua pro functionum ordine adipiscentis. Lib. v. p. 399, *D. Corp. Hum. fab.*

When the study of anatomy thus received a new impulse, other and new investigators, pupils of the school of Vesalius, soon appeared, and amongst them was Fallopius,[1] who was the first to regard the muscular fibres of the bladder, discovered by Galen, and subsequently described by Vesalius, to be of a muscular nature. He even went so far as to include these muscle-fibres amongst the other muscles of the body, and maintained that they were likewise under the influence and control of the will; this conception is shared by many authorities of the present day. Not many years later, Spiegel[2] gave the name of *detrusor urinæ* to the longitudinal fibres of the muscle-coat, because he conceived these were in the main the muscular fibres concerned in the expelling of the urine. The name has since been retained, but there are evident signs of its gradual disappearance from anatomical works, which may well be the case, forasmuch as the fibres which he describes do not form a separate muscle and have not a separate function.

Cowper gives a short description of the bladder in his work entitled *The Anatomy of the Human Bodies*, and published in Oxford 1698:—

"The bladder of urine may be said to be a dilatation of the ureters: the intimate of the membrane of both agree, except that the muscular fibres of the bladder are stronger and larger than those of the ureters; the superior and largest of them embracing the bladder like a hand, as Spigelius compares them; the internal are the less, and decussate the superior with the various angles: some anatomists reckon these among the muscles, and call them *detrusores urinæ*."

Even at this period the muscular nature of the wall of the urinary bladder was not universally acknowledged, nor was its muscle placed amongst the other muscles of the body; indeed, from the above quotation one would gather that only a few anatomists of that period held that the muscle of the bladder deserved such a recognition.

Cheselden, a few years later, gives the following description :—

"The bladder of urine is seated in the pelvis of the abdomen; its shape is orbicular, and its coats are the same as with those of the guts and other hollow muscles already described, viz., an external membranous, a middle muscular, which is the *musculus detrusor urinæ*, and an inner membranous coat, exceeding sensible, as is fully shown in the cases of the stone and

[1] *Obs. Anat.*

[2] *De Corp. Hum. fabricia*, lib. iv. 512.

gravel. The use of this nice sense is, to make it capable of that uneasiness which excites animals to exclude their water, when the bladder is much extended" (1722, 2nd ed., p. 214).

In the above account given by Cheselden, the whole of the muscular coat of the bladder is distinctly recognised as forming the detrusor urinæ, and not only the external longitudinal fibres, as understood by Spiegel; further, the wall of the bladder is compared to the muscular wall of any hollow viscus, such as the stomach. Again, the arrangement of the muscular fibres is supposed to be the same in all of these hollow viscera with muscular walls.

After this there appears to have been no progress in the study of the anatomy of these hollow organs, and especially of the urinary bladder, until the time, comparatively recent, when Mr Ellis gave an account of his researches before the Medico-Chirurgical Society of London in the year 1856. In this account he describes the muscular wall of the bladder as being composed of *three* strata or planes, two of which are thick and complete, while the third is thin and incomplete. In each stratum or plane the muscular fibres run in one definite direction, but the direction differs in each plane; for example, in the external stratum or plane, the muscular fibres run longitudinally from apex to base; in the middle, circularly, and in the internal, obliquely. In addition, he noted that the muscular fasciculi derived from the muscular bundles pass from one stratum to another in order that a thorough and intimate binding of all the strata should be ensured. From this he draws the obvious conclusion that one stratum cannot, in consequence of these muscular fasciculi, contract without the others participating. Therefore all the three strata are like one. Not more than ten years later Dr Pettigrew, who had just completed a very careful and elaborate series of dissections of the urinary bladder, as also of the other hollow muscular viscera in man and in many of the domesticated animals, published the result of his researches in the *Proceedings of the Royal Society*, 1865. The main conclusion arrived at in the paper is that the muscular fibres of all hollow muscular organs are arranged in a series of interlacing figures of 8. This description has not been confirmed by others, and does not seem to me to be warranted by the observations of the Pettigrew specimens which are in the Museum of the Royal College of Surgeons.

Of all the more recent writings on the subject, the one most worthy of notice is that by Professor MacAlister, who, in his recently-published work on Anatomy, modifies in some respects the account given by Ellis. He divides the external layer, which he says is characterised by being of a reddish colour, into several series of groups; these are the (p. 447)

"*Uracho-vesical*, which radiate in three sets; the anterior descend on the front wall, the posterior on the hinder wall from the urachus, and the lateral pass in two series, some oblique, and some directly downwards from the urachus to the prostate. A second set are *pubo-prostatico-vesical*, and radiate on the anterior wall from the attachment of the anterior true ligaments; a third series are *recto-vesical*, coming from the fascia, so named in the male, or *vagino-vesical* in the female. These series freely interlace into a continuous layer, which is sometimes named the *detrusor urinæ* muscle.

From a study of the foregoing extracts it is evident that the dissection of the muscular fibres in the wall of the bladder is beset with no ordinary difficulties.

In my dissections, which have been chiefly conducted on human bladders, I have adopted the common plan of distending the organ, soon after its removal from the body, with strong methylated spirit, so as to render its walls tense and hard.

FIG. 1.—A view of the anterior surface of a dog's bladder distended with spirit. Longitudinal external fibres run from apex towards neck of bladder, where they turn outwards on either side of the middle line, and become more or less transversely disposed; the lateral longitudinal fibres are also shown, also the prostate gland and vasa deferentia. Reduced to two-thirds natural size.

After the removal of the peritoneum, fat and loose cellular tissue, it will be observed that the muscular bundles are collected together so as to form somewhat ill-defined bands. These bands are seen to run in different and varying directions, and, on the whole, the arrangement in the two lateral halves of the bladder is symmetrical. In the middle, in front and behind, there is a broad band, which runs from the apex to the

neck, and which is composed of bundles having a longitudinal direction. Near the neck of the bladder the bundles are gradually lost in the connective tissue, and are not inserted into any special part, such as the capsule of the prostate gland and anterior true ligaments of the bladder. At the apex, the

FIG. 2.—View of left lateral surface of human bladder, which was taken from a man who had suffered from a slight stricture of the urethra. The anterior and posterior groups of longitudinally disposed fibres are shown on the anterior and posterior surfaces respectively; some of the longitudinal fibres on the anterior surface turn outwards and become oblique, offshoots from the longitudinal fibres on the posterior surface becoming transverse or circular in direction. Reduced to two-thirds natural size.

bundles are dispersed and join with others in a dense plexus around the base of the urachus; they are blended with much connective tissue. There are no other bands with bundles having a longitudinal direction on the exterior of the organ, and these two, therefore, constitute the *external longitudinal*

coat, which is incomplete, and which was first called by Spiegel the *musculus detrusor urinæ*. Even these two bands, and especially the one in front of the bladder, are not altogether composed of bundles disposed in a longitudinal manner, for, near the neck of the bladder, many of these bundles may be seen to take an oblique or transverse course around the lowermost segment of the organ, as is shown in fig. 2. It may be mentioned that in the dog's bladder, where the longitudinal bundles are especially abundant on the exterior, they may be readily seen thus coursing obliquely and transversely about the lowest segment of the organ (see fig. 1); and, as in man, they have no special attachment or insertion into the prostate gland or its fascia, but are lost in the connective tissue in the region of the neck of the bladder. The same disposition of the longitudinal and external bundles holds good in other animals, especially the cat, in which the *post-prostatic* portion of the urethra (a part not represented in man) is, as in the dog, elongated. On the lateral surfaces of the bladder, between the anterior and posterior longitudinal bands, other muscular bands are seen taking different directions—oblique and transverse. They change direction, and interlace with one another, and, towards the anterior and posterior parts, pass beneath the longitudinal bands. They are superficial and deep, and they cannot be said to have their point of origin, or that of their termination, at either the apex or neck of the bladder.

Each *band* is composed, as I have already intimated, of several *bundles* of muscular fibres, which, I need scarcely say, are unstriped; these bundles divide and give off branches, which join with similar branches from adjacent bundles, and in this way form a network connecting the several bundles in a band. In like manner each band is connected with neighbouring bands by fasciculi of muscular fibres, so that the several bands, like the several bundles in each band, are connected by intervening muscular fibres, and the uniformity of action of the entire thickness of the wall of the bladder is ensured, as stated by Ellis. In accordance with what is said above regarding the arrangement of the muscular bands in the wall of the bladder, a section in the mesial line shows two more or less distinct coats, the one external or longitudinal, with its fibres running parallel to the

line of section, and the other internal or circular, with its fibres running across it. In all bladders that I have examined and obtained, the inner or (apparently) circular layer is at all ages and in all degrees of distension the thicker. This is best exemplified in cases of bladders hypertrophied in consequence of some mechanical obstruction to the outflow of urine, for in these the internal coat usually becomes three or four times as thick as the external.

Trigonum Vesicæ.

The trigone of the bladder, first described by Lieutaud and often named after him, is formed by the close binding together of the innermost bands of the muscular fibres of the bladder in the situation between the level of the openings of the ureters and the urethro-vesical orifice; their binding together is effected by means of a considerable amount of a somewhat dense fibrous connective tissue. In its density the trigone resembles the non-striped muscular coats of the urethra, and, as in them, the range of movement is limited. In this respect it is very unlike the remainder of the wall of the bladder, whose range of movement is very free and very great; and owing to this it does not yield during distension of the organ, and it varies but little in its superficial extent and in its thickness in the different states of distension that the bladder assumes.

As I have mentioned, the trigone is composed only of the innermost bands of muscular bundles, while the outermost band, which is here longitudinal, passes onwards towards the neck of the bladder without becoming incorporated in the dense trigone. This outermost band is separated, as may be seen in saggital sections, from the trigone proper by means of a thin and delicate layer of loose connective tissue, and it may consequently be easily depressed behind and beneath the trigone, which is left as an upstanding edge, upon and beneath which the mucous membrane is reflected, as may be seen in cases of long-continued retention. Thus is formed the retro-uretral pouch, so commonly associated with enlarged prostate and retention. I have found the trigone as a distinct structure only in man and some monkeys, and I conclude therefore that it may have some relation to the erect posture.

Internal Sphincter of the Bladder.

Galen[1] considered some such structure necessary, and Vicary[2] says "the neck [bladder] is carnous and hath muscles to witholde and let go [urine];" but Vesalius seems to have been the first to describe it as a distinct muscle. Sir Chas. Bell[3] gives a full and minute description of it as the *sphincter vesicæ internus*, and maintains that it can be easily demonstrated by turning the bladder inside out and reflecting the mucous membrane. Wilson[4] and Guthrie,[5] however, failed to corroborate the view of Vesalius, upheld so strongly by Bell. In quite recent works on anatomy, such as Cruveilhier's *Anat. Descriptive*, this sphincter muscle is represented only in the male between the base of the prostate gland and the anterior wall of the bladder in front, not behind, and not in any part of the female bladder and urethra.

Although I have investigated this matter with great care in numerous bladders taken from both sexes and of all ages, yet I cannot say that I have met with a single instance where there was a thickening of muscle around the commencement of the urethra sufficient to constitute a sphincter, or indeed anything approaching one. What is thus described as a special muscle I find to be nothing more than a few of the outer bundles of the muscular wall of the bladder passing through some loose connective tissue between the base of the prostate gland and the wall of the bladder before becoming lost in the connective tissue of this region and perhaps in the capsule of the gland. I may here, for the purpose of making the matter more clear, refer to what I have written in a former paper on the "Prostate Gland" published in the *Journal of Anatomy and Physiology*, vol. xxiii. p. 381.

But, as already said, there is no thickening of the muscular fibres at the neck of the bladder such as deserves the appellation of sphincter or such as to act as a sphincter. The process of retention and expulsion of urine I propose to consider in a subsequent paper (Part II.).

The Urethra.

In man the urethra is anatomically divisible into *three* parts —namely, prostatic, membranous, and penile, each part corresponding to a definite and well-known region.

[1] *Loc. cit.* [2] *Loc. cit.* [3] *Trans. Med. Chir. Soc. Lond.*, vol. i.

[4] *Lect. on the Urinary and Genital Organs*, 1821, p. 57.

[5] *Anat. and Dis. of the Bladder*, p. 15.

When, however, the urethra is studied from a comparative anatomy standpoint, or from that of embryology, it will be observed that it is made up of two main portions—a *first* or urinary, which extends from the neck of the bladder to the point where the *vasa deferentia* open into the urethra, and which comprises the upper part of the prostatic region in man; and a *second* or *genital* (genito-urinary) portion, formed by the fore part of the prostatic, membranous, and penile portions. I call attention to this morphological and physiological division of the urethra in order to elucidate some of those physiological problems, to be subsequently considered, that arise in connection with the normal retention and expulsion of urine and semen.

In the lowest order of Mammalia, the monotremata, the urethra in the male is short and opens into the uro-genital sinus, and serves only to convey urine. The *first* or urinary portion extends from the neck of the bladder to the level of the entrance of the *vasa deferentia* into the urethra. The muscular wall of this part of the canal is composed of layers of non-striped muscle only, which are continuous with those of the bladder on the one hand and those of the *second* or genital portion of the urethra on the other. (The length of this part varies in different animals.) In man it is very short, measuring only from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in length; but in the dog it is longer, and in the cat it usually measures about 2 inches.

The first (or *urinary* part) consists of three coats—the *internal* or mucous coat, composed of loose connective tissue, in which there are numerous veins, is lined by transitional epithelium, like that covering the mucous membrane of the bladder; a *middle* or muscular coat is composed of an inner incomplete longitudinal layer in separate bundles, and an outer, thicker, circular layer, both these layers being traceable in serial transverse sections from the neck of the bladder downwards, and found to be directly continuous with the muscular layers (the so-called inner oblique and middle circular) of the bladder; an *outer* fibrous coat composed of loose connective tissue. This first part of the urethra serves to convey urine from the bladder to the *second* or genital part of the urethra, or into the uro-genital sinus or cloaca as the case may be.

The second or genital (*genito-urinary*) part extends from the

openings of the *vasa deferentia* into the urethra to the end of the penis, and is the part developed in the male for the purpose of safely conveying the semen into the receiving organs of the female. It is made up of, as I have stated above, the fore part of the prostatic, the membranous and the penile portions of the urethra. The minute structure of each of these parts is so well known and so fully described in most anatomical text-books that I need hardly refer to it here. This, the second or genital part of the urethra, is covered externally by a sheet of striped muscle, which begins at or about the level of the entrance of the *vasa deferentia* into the urethra, and extends to within two or more inches of the *meatus urinarius*. This sheet of striped muscle is, at its beginning, represented in man by a few transverse fibres on the anterior or ventral surface of the lower or distal half of the prostate gland. They rapidly, however, increase in length, so as to extend on each side of the urethra dorsalwards, and at the beginning of the membranous part they more or less completely encircle the tube. The fibres on the anterior or ventral surface of the prostate gland constitute the "external sphincter" of Henle; but inasmuch as they are not disposed in a sphincter-like fashion, and do not form a distinct muscle, rather the beginning of the sheet above referred to, they hardly deserve to be designated by a special name. The part of this sheet around the membranous part of the urethra is termed the *constrictor urethra;* and the muscle in this situation does not form a complete ring of uniform thickness around the tube. It is in transverse section of the urethra in the form of a crescent, something like a horseshoe with the thickest part in front or ventrally, and the pointed extremities fixed to the connective tissue of the hinder or dorsal wall, as is represented in the urethra of the Hedgehog. This muscle is thus fixed only at the extremities of the crescent, the remainder being free to contract and compress the urethra. Again, the part of the sheet around the senile portion is termed the *accelerator urinæ,* which needs no description, as its arrangement and disposition is well known. It is interesting in this connection to make the following quotation from the works of Jno. Hunter (*Animal Economy,* ed. by Palmer, p. 39).

"I shall call these [acceleratores urinæ] muscles *expulsores semi-*

nis, as I apprehend their real use to be for the expulsion of that secretion [*semen*]; these muscles likewise throw out those drops of urine which are collected in the bulb from the last contractions of the bladder; and they have, from this circumstance, been called *acceleratores urinæ;* but if a receptacle [meaning the bulb] had not been necessary for the semen, those muscles had probably never existed, and the last drops of urine would have been thrown out by the action of the bladder and urethra, as in some measure is the case in the castrated animal."

The name suggested by Hunter may with much appropriateness be applied to the whole sheet of striped muscle around the urethra, for it all has the same function as those designated by him the *expulsores seminis.*

I do not, of course, ignore the use of this muscle in expelling urine from the urethra as well as in closing the urethral canal.

The Changes in the Striped Muscle of the Urethra in Rutting Animals during the Rutting Season.

The division of the urethra which I have adopted in the preceding pages, and which is based upon a study of the physiological uses of its parts rather than upon convenience in description, receives additional support from observations that I have made upon the periodic changes that occur in the striped muscle around the urethra in those animals which have a rutting season: and also upon the alterations that supervene in the structure of the muscle after complete castration in some of the domesticated animals and in man.

In the rutting animal the structural changes in the muscle go *pari passu* and correspond with the changes that occur in the testicles and the accessory sexual glands. As the latter increase in size and activity of function so does the muscle increase in size and in the tranverse striation of its fibres. As the glands shrink so does the muscle lose its structural evidence of functional activity. For instance, in the Hedgehog in midwinter the striped muscle around the second or genital part of the urethra (that around the membranous part selected) is pale and about 1–1·5 mm. in thickness; the muscular fibres are small and atrophied, showing well-marked longitudinal but only faint transverse striation (fig. 3), and they are separated by much

fibro-cellular connective tissue. In midsummer, when sexual activity is at its height, the same muscle is reddish in colour and about twice as thick (2–3 mm.); the muscular fibres are large, presenting the well-known appearances of an active, healthy, skeletal muscle; the longitudinal striation is hardly perceptible, but the transverse well-developed; the fibres are close to one another with only a small amount of intervening

b.

FIG. 3.

delicate connective tissue. The increase in the thickness of the muscle is entirely due to the enlargement of each fibre and not to any new formation of muscular fibres. I have determined the number of muscular fibres, and they are practically the same in each instance. The same is true of the Mole.

The Changes Induced in the Striped Muscle of the Urethra after complete Castration.

Attention was first drawn to this subject by John Hunter, who, in his work on *Animal Economy*, refers to it in the following terms :—

"On the contrary, in the castrated animal, the penis is small and not capable of much dilation ; the corpus spongiosum is less vascular; the cavity at the bulb is little larger than the canal of the urethra; and the muscles are white, small, and have a ligamentous appearance. The same observations are true if applied to the erectores penis."

I have been able to confirm the above observations, and may in addition add that the striped muscle around the membranous fore part of the prostatic urethra suffers in like manner, and becomes tough, fibrous, and ligamentous, just as the special muscles of the penis. This may be observed in the bullock, gelding, and other castrated animals. That such is the case in man, may be gathered from the observations of Gruber, Bilharz, and Pelican, to which I have referred in a paper already published by me on the prostate gland (see *Jour. Anat. and Phys.*, vol. xxiv. p. 35).

In a full-grown cat, castrated when a few weeks old, I found that the fibres of the striped muscle-coat were greatly atrophied, with loss of transverse but increase of longitudinal striation, and great development of connective tissue between the fibres which were much separated; this corresponding closely with the condition found in the Hedgehog in mid-winter.

Conclusions.

1. The muscular fibres of the wall of the bladder are collected into broad bands, two of which, from 1 to 2 inches in width, have an external longitudinal direction from the apex to the neck on the middle of the anterior and posterior surfaces. They are the "detrusor urinæ" and form the "external longitudinal coat." The other bands, which form the greater part of the wall, have an oblique or transverse direction, crossing over and under one another, and often changing their direction; these, unlike the former, have no special point of attachment.

2. Each band is composed of anastomosing bundles of muscular fibres, and all the bands are connected with one another by means of intervening muscular fasciculi. All the bands thus connected act together harmoniously.

3. The *trigonum vesicæ* is formed by the innermost bands, the muscular fibres of which are closely and firmly bound together by fibrous connective tissue; the outer longitudinal band passing onwards to become lost in the neck without being incorporated, being, in short, separated from the trigone by loose areolar connective-tissue. It is this arrangement that allows of the easy formation of the retro-uretral pouch, in cases

of long-standing difficulty in emptying the bladder and especially if accompanied by retention.

4. There is no thickening of the so-called circular coat of the bladder at the neck, to constitute an "internal sphincter," neither in the male nor female.

5. The striped muscle around the genital part of the urethra is developed especially in relation to the sexual function.

THE OCCURRENCE OF HÆMOGLOBINURIA IN BLOOD-PRESSURE EXPERIMENTS.[1] By JOSEPH TILLIE, M.D., *Assistant to the Professor of Materia Medica in the University of Edinburgh.*

IN the course of an investigation on "The Pharmacology of Curare and its Alkaloids" (*Jour. Anat. and Physiol.*, vol. xxv.) I recorded (pp. 45 and 52) that during the blood-pressure experiments on rabbits which had been paralysed by small doses of curarine, where, in consequence of vaso-motor spasms, great variations in blood-tension occurred, the urine became blood-coloured after about an hour. No opportunity of continuing the observations on this condition of the urine has occurred until now.

A brief repetition of the previous experiments led to the same results.

No blood-corpuscles were detected on microscopic examination of the crimson-coloured urine. Spectroscopic examination showed the presence of oxyhæmoglobin.

On making a number of experiments under exactly similar conditions to those in which hæmoglobinuria occurred, with the exception that the carotid artery was not in connection with the manometer, no hæmoglobin appeared in the urine; but albumen was occasionally found. Also, no hæmoglobinuria occurred when the artery was in connection with the manometer if the blood-pressure was only recorded for brief periods, the artery being clamped after each short tracing, and the manometer-tube and cannula emptied and refilled with fresh 20 per cent. sodium carbonate solution.

In blood-pressure experiments a certain quantity of blood necessarily mixes with the soda, and this results in solution of the red corpuscles. On filtering the mixture in the manometer-tube a clear crimson solution is obtained. In experiments of some duration, therefore, where free communication between the artery and the manometer is maintained, and

[1] From the Pharmacological Laboratory of the University of Leipzig.

where, as in these experiments on rabbits, great rises of blood-pressure occur, each period of relatively low blood-pressure must indicate that a quantity of soda-hæmoglobin solution has passed back into the carotid artery and along the nearest branch into the general circulation. After a time a hæmoglobinuria occurs; but it is not due to the action of the poison. When the blood-pressure is very steady, or when the change throughout an experiment is in the form of a rise, or when death quickly follows a considerable fall of pressure, the urine, naturally, is not likely to contain hæmoglobin from this source—a source of fallacy not generally recognised.

OSSIFICATION IN THE HEAD OF THE HUMERUS AT BIRTH.[1] By HERBERT R. SPENCER, M.D., B.S. (Lond.), M.R.C.P., *Assistant Obstetric Physician to University College Hospital.*

DURING the last four years I have examined the head of the humerus on both sides in 180 fresh fœtuses, which were either still-born or died shortly after birth; of these 107 were males, 69 females; in four the sex is not stated. In fourteen cases (all still-born) I found a well-marked centre of ossification in the cartilage forming the head of the humerus; in twelve of these it was observed in both humeri, in two it occurred only on one side.

The centre appears on section as a red bony deposit, usually about the size of a "No. 6" shot; often it is larger than this, and occasionally somewhat smaller (specimens shown).

Many of the fœtuses were premature, some being only of four or five months' development. I am unable to state exactly how many were mature; but some idea may be obtained from the following table of the weights of the fœtuses examined:—

There were[2]	under	2	lbs.	14	fœtuses.
"	"	3	"	15	"
"	"	4	"	21	"
"	"	5	"	23	"
"	"	6	"	33	"
"	"	7	"	34	"
"	"	8	"	14	"
"	"	9	"	10	"
"	"	10	"	3	"
"	"	11	"	1	"
"	"	12	"	1	"
"	of unstated weight			11	"
		Total,		180	"

From this table it will be seen that only 74 fœtuses weighed 6 lbs. or more, and I think that there will not be much error in

[1] Communicated to the Anatomical Society, May 1891.

[2] "Under 2 lbs." means weighing 1 lb. or more, but less than 2 lbs.

assuming that there was about that number of mature fœtuses. This would give the frequency of the occurrence of a centre of ossification in mature fœtuses as 14 in 74 cases, or nearly 19 per cent.[1] Or, if we reckon all fœtuses over 5 lbs. in weight as full-term fœtuses, the proportion would be 14 in 107 cases, or over 13 per cent.[1] This figure is undoubtedly too low, but neither this nor the preceding figure has any statistical value, except as showing that ossification in the head of the humerus is not rare in full-term fœtuses at the time of birth.

Table of Fourteen Still-born Fœtuses in which a centre of ossification was found in the head of the humerus.

No.	Sex.	Length.	Weight.	Remarks.
1	M.	?	7 lbs. 8 oz.	(without brain and blood; craniotomy).
2	F.	20½ inches.	6 „ 13½ „	
3	F.	18 „	5 „ 10 „	(anencephalus).
4	F.	21¼ „	8 „ 12 „	
5	M.	22 „	8 „ 0 „	
6	M.	18½ „	7 „ 9 „	
7	M.	22½ „	9 „ 8 „	
8	M.	18½ „	5 „ 9½ „	
9	M.	21 „	6 „ 8 „	
10	F.	20½ „	7 „ 12 „	
11	F.	22 „	7 „ 13½ „	
12	F.	?	9 „ 5½ „	(without brain and blood; craniotomy).
13	M.	21½ „	6 „ 6½ „	(without brain and blood; craniotomy).
14	M.	21 „	7 „ 0 „	(without brain and blood; craniotomy).

If we confine our attention to large fœtuses,—*i.e.*, to those weighing 7 lbs. or more,—it will be seen that forty such cases were investigated, and in nine the centre was found, that is to say, in 22·5 per cent.[1]

Large size of the fœtus, however, does not necessarily entail ossification in the head of the humerus, for the centre was absent in the two largest fœtuses, which weighed respectively

[1] The proportion is really higher than this, inasmuch as the "fœtuses of unstated weight" are here assumed to be large fœtuses.

11 lbs. 4½ oz. and 10 lbs. 12 oz. All fourteen fœtuses in which ossification was observed were probably mature, for they all had well-developed ossific centres in the lower end of the femur, and were mostly of large size, as will be seen on reference to the preceding table.

With such leisure as I have for a research of this sort, and with the kind aid of Professor Thane, I have looked into the literature upon ossification of the head of the humerus.

Amongst the older writers upon the fœtal skeleton, I find that the following either make no mention of the condition of the head of the humerus at birth or state that it is entirely cartilaginous :—

Fallopius, "Opera omnia," 1600.
Riolanus, "Osteologia infantis," 1613.
Spigelius, "Opera omnia : de formato fœtu," 1645.
Eyssonius (and Coiter), "De ossibus infantis," 1659.
Sylvius, "Opera medica," 1680.
Ruysch, "Catalogus rariorum," 1691.
Baker, "Cursus osteologicus," 1699.
Kerkringius, "Osteogenia fœtuum," 1717.
Nesbitt, R., "Human Osteogeny," 1736.
Schwarz, "Disputatio de ossium epiphysibus, 1736.
Ungebauer, "Epistola osteologica de ossium trunci corporis humani epiphysibus," 1739.
Platner, J. Z., "De ossium epiphysibus," 1739.
Tarin, "Des os du fœtus en général. 1753.
Monro, "Anatomy of the Human Bones and Nerves," 1758.
Ollivier, "Des indications qu'on peut tirer d'un seul examen des os du fœtus," 1842.

The time of appearance of ossification in the head of the humerus is variously given by modern authors; in the following, amongst others, there is no mention of its occurrence at the time of birth :—

Quain, "Anatomy," 1890, gives date of ossification in the "first year."
Gray, "Anatomy," 1887, gives date of ossification "at the beginning of the second year."
Macalister, "Anatomy," 1889, gives date of ossification "fifteen months after birth."
Ogston, "Med. Jurisprud.," 1879, gives date of ossification "at one year."
Taylor, "Med. Jurisprud.," 1883, gives date of ossification "at one year."

TIDY, "Legal Medicine," 1882, gives date of ossification "at one year."

RAMBAUD and RENAULT ("Origine et dévelop. des os"), 1864, give date of ossification "towards the middle of the first year."

CRUVEILHIER, "Traité d'anat. descrip.," 1877, gives date of ossification "at the beginning of the second year."

SAPPEY, "Traité d'anatomie," 1866, gives date of ossification "some months after birth, usually at the third or fourth."

TESTUT, "Traité d'anat. humaine," 1889, gives date of ossification "from the second to the fourth month after birth."

HERTWIG, O., "Entwickelungsgeschichte," 1888, gives date of ossification "at end of first or beginning of second year."

SCHWEGEL, "Entwickelungsgeschichte," 1858 (Tables), gives date of ossification "at first to fourth year."

In the body of the work, however, the last-named author says that it often appears immediately after birth.

In only three authors have I been able to find any reference to the occurrence of ossification in the head of the humerus at the time of birth, viz., in

1. HENLE, "Knochenlehre," 1877: "At the time of birth the ends of the humerus are, as a rule, still perfectly cartilaginous. Ossification of the head begins with a globular nucleus, which appears, as a rule, in the third month, seldom earlier, and at the end of the first year has reached the size of a pea; its appearance may, however, be delayed until the second year."
2. KÖLLIKER, "Entwickelungsgeschichte," 1884: "At birth, with rare exceptions (which affect the upper epiphysis), both epiphyses are completely cartilaginous."
3. SPIEGELBERG, "Text-book of Midwifery" (*New. Syd. Soc. Trans.*), 1887: "Centres of ossification appear in the upper end of the tibia, and, in rare instances, in the upper end of the humerus, towards the end of the tenth month" (intra-uterine).

The above three quotations resemble each other in form, and the information they convey may possibly have been derived from a common source, and seems to have been the result of some previous observation; I have been unable, however, to find any record of such observation.

In any case, a consideration of the fourteen observations detailed above shows—

(1) That a centre of ossification is not rarely met with in the head of the humerus of mature fœtuses at the time of birth;

(2) That in large fœtuses (*i.e.*, weighing 7 lbs. or more) the centre is commonly observed—in my own cases, in at least 22·5 per cent. This frequent occurrence in large still-born children would seem to have some medico-legal importance.

In conclusion, I wish to express my thanks to the Anatomical Society for the opportunity of reading this short paper, which, as it calls attention to a fact not referred to, I believe, by any British author, I thought might not be altogether devoid of interest.

FUSIBLE METAL INJECTIONS. By CHARLES W. CATHCART, F.R.C.S. Eng. and Edin.

THE use of easily fusible metal as an injection mass is by no means new. Among the specimens bought from Sir Charles Bell, by the Royal College of Surgeons of Edinburgh, about the year 1830, are several beautiful metal casts of the semicircular canals of the internal ear. Professor D. J. Hamilton lately told me that his father, the late Dr Hamilton of Falkirk, about thirty years ago injected the air passages with fusible metal. Professor Crum Brown also made fusible metal casts of the semicircular canals about fifteen years ago. Since that time Dr Ewart, Mr Stoneham, and no doubt many others, besides myself, have used the same material. No one, however, so far as I know, has used the same method as myself for injecting the fusible metal, and as it has succeeded in some ways very well, it seems right to publish it.

This method was worked out in 1880–81, and I showed a series of fusible metal injections at the meeting of the British Medical Association in 1882. I delayed publication in the hope of being able to carry out some systematic research. This, however, I have not found time to do, so last winter Dr Miles kindly undertook some applications of the method for me with the view of publication. These he will describe at the end of this paper.

I was led to the use of fusible metal for studying the relative shape of fine vessels by the brittleness of the ordinary wax corrosion masses. On applying to Dr Stevenson Macadam I was referred to the alloy given in Bloxam's *Chemistry* under Cadmium. The ingredients are "three parts of Cadmium, with sixteen of Bismuth, eight of Lead, and four of Tin" (6th ed. p. 296). This is said to fuse at 140° F. (60° C.), but in practice a temperature of between 160° and 170° F. is generally required before the metal will flow properly. Although several other proportions of the same metals have been published, none seem to me so good as the above. At the same time a hard alloy,

fusing at, say, 120° F., would be of very great service if it could be obtained, as no doubt it could be if special attention were paid to the subject by some competent chemist.

The method I have adopted consists in heating the tissue in steam up to the fusing-point of the metal, which is then melted and allowed to flow into the vessels by its own weight as in an injection with mercury. The least draught of cold air solidifies the molten metal, so a special apparatus had to be constructed. This is quite simple, and was made at my suggestion in its respective parts by a tinsmith and a carpenter. The essential part of the apparatus is a double tube—the inner (about $\frac{1}{4}$ inch) for the metal, and the outer (about $1\frac{1}{2}$ inches) for hot water, which thus surrounds the inner tube (fig. 1).

Corresponding to each tube, and fixed to it, is a funnel. The larger of the two is of tin, and has a cover soldered over it, but

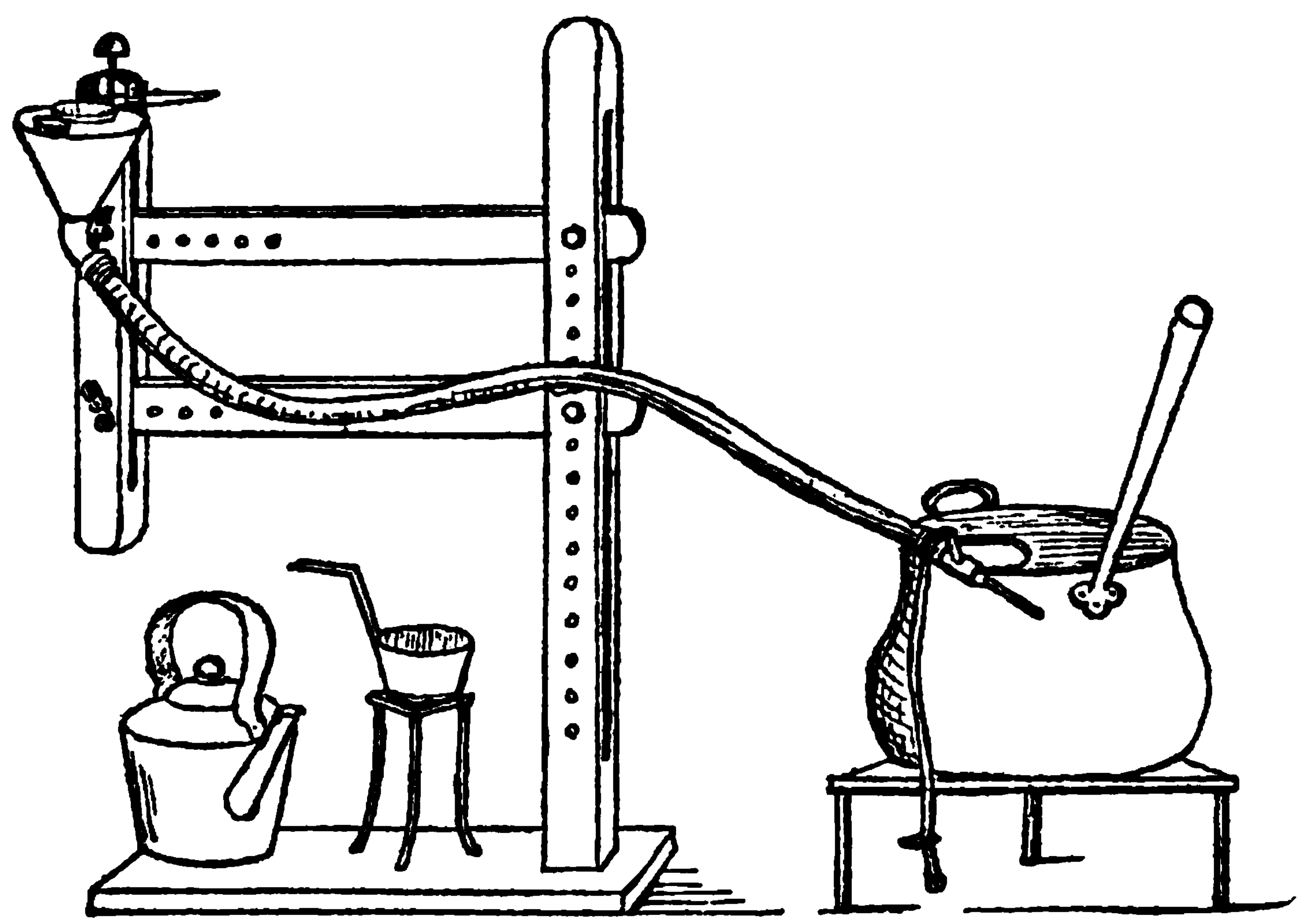

FIG. 1.—Sketch of Apparatus.

in the cover two apertures are left—one in the centre for the smaller funnel, the other near the margin for filling in hot water. The smaller of the two funnels, made of copper, fits within the larger, but projects at its open end above it for about $\frac{1}{2}$ inch. (This is to prevent any water from overflowing from the outer funnel into the inner one.) About 3 feet of the outer

tube are required; the inner one needs to be about 6 inches longer.

The lower end of the outer rubber tube is slipped over a piece of tin tube about 2 inches in length. Into the other end of this tube is soldered about ½ inch of a smaller one, *i.e.* just wide enough to allow the smaller rubber tube above mentioned to pass through. Besides this, into the side of the larger tin tube is soldered a second smaller one of about the same size as the first. On to each of those smaller tubes is fixed a piece of rubber tubing that at the side is about 2 feet in length and is closed at the end with a clamp or stopcock. The other is about 3 or 4 inches in length.

When the apparatus is about to be used, the inner tube and funnel is passed inside the outer funnel and attached tubes until it projects through the smaller rubber tube fixed to the lower end. It is then attached to a glass nozzle, which in turn is tied into the vessel to be injected. The interval between the innermost rubber tube and the tube through which it passes now alone remains to be closed. This is done by tying the outer of the two down upon the inner at the place where the latter is fixed to the glass nozzle (fig. 2). If the funnels are held uppermost, the side tube being closed, the outer may be filled with water so as to surround the inner tube and funnel. Water cannot flow into the inner tube if the attachments are made fast, neither can it overflow from the outer funnel, because the upper end of the inner funnel is the higher of the two. So much for the first part of the apparatus.

FIG. 2.

The stand for the above is arranged so that the height of the funnels may be altered with as little disturbance as possible. An upright bar of 2 feet 6 inches is fixed into a stout board 1 inch thick, and 3 feet by 1½ feet. To the upright is attached a parallel lever-arm, working in a vertical plane, and fitted with thumb-screws, so that it may be secured at any desired point. The outer funnel is then clamped to the end of the lever-arm, and the distance between the two levers is arranged so that when the outer funnel is in position its lower end is nearly on a

level with the lower of the two lever-arms. (This is not brought out in the sketch.) The object of this is to allow of the funnel being raised without disturbing the lower end of the tube, which is fastened to the upright as it passes it. (This fastening has been omitted in the drawing for the sake of clearness.)

The organ or tissue to be injected is then supported in the pot, allowance being made for some shrinking by the heat. About an inch of water is kept at the bottom of the pot. A small gas jet beneath the pot keeps it hot. On the top of the pot is laid a glass cover, in which a notch is cut near the circumference. This is to allow the large indiarubber tube to enter the pot, and the smaller—clamped one—to leave it. At the same notch a thermometer is inserted. All the intervening corners are then filled with cotton-wool, which excludes cold air, but allows steam to escape. To supplement the use of the thermometer a piece of the fusible metal should lie exposed and within reach of the thermometer, or of a stick passed in at the notch. This metal is to act as an index of the temperature required for fusing. When this point has been reached, it must be maintained by careful adjustment of the gas flame for thirty to sixty minutes, or longer, according to the mass of tissue. A kidney, for instance, I would leave for about half an hour.

After the tissue has been heated, the tubes have to be heated up also. This is done by pouring boiling water into the outer funnel, and allowing it to escape by the clamped side-tube before mentioned. After this has been done several times, a final quantity of hot-water is left in the outer tube and funnel. The lever-arm is then depressed, and the metal having been heated in a small metal pot in boiling water, or over the gas, is poured into the inner funnel until it has filled the upper part of the tube and stands in the funnel. A cap is then laid over the inner funnel to exclude cold air, and the lever-arm is steadily raised. Sometimes, but not always, the metal can be seen to pass through the glass nozzle, or to move the specimen as it enters it. Vapour, however, generally obscures the glass top on the pot, and one can only tell that the injection has succeeded when the tissues are being digested away. An increase of weight of the specimen is always a hopeful indication.

A few minutes have generally been long enough in my hands

for the actual injections, but a longer time might sometimes be advisable. In such a case it would be necessary to renew the hot-water in the outer funnel from time to time. So long as this is done, and so long as the flame is kept up below the pot, the metal will remain fluid.

As soon as the injection is considered finished, the glass cover should be drawn aside, a ligature applied above the nozzle, and the rubber tubes divided above the ligature. This is to allow the metal in the inner tube to run out. Should it not do so, the metal requires to be cleared out of the inner tube by boiling it, and running hot-water through. Little or no metal sticks to the copper, as it would do to tin.

The next stage consists of getting rid of the soft tissues round the metal casts of the interior. This might be done by putrefaction, but the process is slow and disagreeable. Solution in strong caustic potash or soda does well, but the metal may be thereby affected. What seems to be the best is rapid removal of the soft parts by artificial digestion, at a temperature of about 100° F.

Fairchild's pancreatic powders have acted well in my hands, but a solution of papain has acted still better. If either were chosen, a quantity would be prepared in a wide-mouthed jar; in this would be suspended the specimen, and the jar would then be placed in an incubator. In successful cases, as the soft parts melt away the fine casts of vessels, &c., become more and more apparent.

Finally, after the soft parts are entirely gone, the specimen may be suspended dry, or in water or in alcohol; or the main vessels may be embedded in a stand of plaster of Paris, and kept under a glass cover.

It will be seen from the above description that in order to ensure a perfect cast the high temperature to which the structure must be heated must alter the tissues. This it does in the way of contraction. Still the relative size of the vessels, &c., is maintained, as well as their mode of branching and general arrangement.

SOME APPLICATIONS OF THE METHOD OF INJECTING WITH FUSIBLE METAL. By Alexander Miles, M.B., F.R.C.S.E.

At the request of Mr C. W. Cathcart, I have recently made some experiments on the injection of various organs with fusible metal, after the method, and with the apparatus, devised by him. Among others, the following organs were repeatedly injected, the lungs, the brain, and the kidneys, and several times an injection of the whole arterial supply of the head was attempted.

I shall not in the present paper enter in detail into an examination of the resulting casts, but shall merely indicate one or two practical points to which attention must be paid in making such preparations.

Lung. — Whether the "bronchial tree" or the blood-vessels are to be injected, it is essential that the pleural covering of the lung be intact, and any cuts or tears which may have been made in it, during the removal of the viscus from the body, must be carefully secured with ligatures.

Should a severed piece of lung only be available for injection, or should it be desirable to inject a limited portion, the selected area must be isolated from the rest by *elastic* ligatures tightly applied so as to occlude the vessels without tearing them through.

When such precautions are neglected, the fluid metal runs right through the lung at points, and only detached areas of the organ get filled with the injection mass, and these in the process of maceration become separated, so that the relative position of parts is lost.

While the lung is being heated, previous to injection, it may be allowed to float in the water, but a thick pad of wool should be placed in the bottom of the vessel, so that when it sinks by the weight of the metal entering it, the fine vessels will not be broken. The greatest possible care must be taken to prevent any pressure being made on the

cast during maceration, as the casts of terminal vessels are very readily broken off when about the diameter of a human hair.

Results. — In successful preparations, the whole of the bronchial tree, from its origin at the bifurcation of the trachea to the ultimate air-vesicles (fig. 3), forms a continuous solid injection, which illustrates the mode of ramification of the bronchi and bronchioles, and the distribution on them of the infundibula and air-vesicles. In one case, where I succeeded in injecting the air-tubes and arteries in the same specimen, the relations of these to one another is well shown (fig. 4).

Fig. 3.—From an enlarged photograph of a cast of the air-vesicles.

It has been found that the injection of collapsed lung is more frequently successful, and the resulting cast more perfect than when the lung is in its usual condition after death.

Fig. 4.—From a photograph.

Brain.—With one exception, I have tried the injection of the brain in the lower animals only, as I have been unable to procure a complete human head sufficiently fresh for the purpose.

The single human brain injected had been for a lengthened period in spirit, and was very unsuitable for my purpose. In applying Mr Cathcart's method to the brain, the following difficulties have been met with:—(1) Unless all the arteries anastomosing with the branches of the internal carotid be secured the metal escapes by them, and so fails to fill the cerebral vessels; (2) the fresh brain tends to become soft when subjected to a high temperature, and great care is necessary to prevent its falling to pieces, and so depriving the vessels of their support; (3) when the brain is hardened in spirit, or even in Müller's fluid, the vessels undergo some amount of shrinking, so that the metal finds increased difficulty in forcing its way through them; (4) unless the dura mater be cut in several places before the tissues are heated, it shrinks to such an extent as to compress the brain, and interfere with the entrance of the metal into its vessels. With care and perseverance all these difficulties can be overcome, and fairly successful casts obtained.

Results.—In the single human brain injected the conditions were very unfavourable, and the injection did not pass beyond the circle of Willis, but of that the cast was perfect. In the brains of sheep, however, better results were obtained. The meningeal vessels, the large vessels at the base, as well as some of those extending for some considerable distance into the brain substance, were well injected. The "rete mirabile," at the side of the sella turcica, was particularly well shown in one or two specimens. The results obtained were such as to encourage one to persevere in the attempt to obtain a method of hardening without shrinking the brain and rendering it brittle.

KIDNEYS.—I have obtained one fairly good injection of the vessels of the kidney, but, as a rule, I found the heat caused considerable contraction of the organ. Mr Cathcart has been more successful in some experiments he made.

THE WHOLE HEAD OF SHEEP.—The injection of this specimen was very successful. The skull-cap was removed that the dura might be cut into to prevent it shrinking and compressing the brain. It was left in position, the calvarium replaced, and the scalp stitched up. The vertebral arteries were tied, and the canula introduced into the common carotid artery.

Results.—Almost all the branches of the external carotid arteries on the face and sides of the head were filled, a complete injection of the tongue and of the Schneiderian membrane of the nose, as well as of the meningeal vessels at the base of the skull was obtained. The large vessels at the base, including the "rete mirabile" and some of the intra-cerebral blood-vessels, were well injected.

THE MUSCULAR MECHANISM OF WALKING. By W. RAMSAY SMITH, B.Sc., *Demonstrator of Anatomy, Edinburgh School of Medicine, Minto House.*

THERE are certain functions of the human body that appear at first sight very easy to understand; but yet when one has studied them for some time, with a few side lights cast upon them, one hesitates to offer any opinion regarding them. Of this nature are several problems possessing a psychical as well as a physical aspect, such as binocular vision and hearing, which, when brought to the touchstone of psychology and comparative physiology, make a thinker hesitate to give an opinion and a practical man to say in despair *Solvitur ambulando.*

But there are also problems of a more purely physical nature, whose solutions, apparently at first sight easy, present many difficulties whenever one tries to bring a hypothesis face to face with all the facts. A great deal has been done by way of describing the mechanics of walking. W. and E. Weber, von Meyer, Marey, Vierordt, Lucæ, Carlet, Pettigrew, Ward, and latest, Braune and Fischer,[1] have contributed to elucidate one aspect of the problem; and Goodsir, Humphry, Morris, and others have investigated another. But while much has been done on the one hand to discover and record the movements of the various phases of walking, and a large amount of study has been bestowed upon the anatomical details of the organs of locomotion on the other, there is a considerable hiatus in our knowledge of the problem of walking; in other words, although we know what acts are performed in walking, and what means are at the disposal of the walker for performing those acts, we have still to learn almost everything regarding the modes or methods in which the means are employed.[2]

[1] For a knowledge of the work of these two last investigators I am indebted to Dr Symington, who also guided me to other literature and discussed several of the points touched upon in this paper.

[2] I ought to mention here Cleland's suggestive paper on "The Actions of Muscles passing over more than one Joint" (*Journal of Anatomy and Physiology*, vol. i. p. 85), which I had not read when the above was written. It deals with the subject of muscular action in the way I desiderate, and in some parts runs on lines similar to those of my present communication.

The incompleteness of our knowledge of the problem of walking was pressed upon my attention by reading Cunningham on the action of the knee-joint. In a passage that may be taken as setting forth the generally received theory of the action of certain muscles, he says—

> "The muscles which operate upon the bones of the leg so as to produce flexion and extension of the limb at the knee-joint are:—(1) *extensors*, the four parts of the quadriceps extensor; (2) *flexors*, the biceps, popliteus, sartorius, gracilis, semitendinosus, and semimembranosus. Of these, only one is inserted on the outer side of the limb, viz., the biceps. The other five are inserted into the tibia on the inner side of the leg. This preponderance of muscles attached to the inner aspect of the leg is, no doubt, associated with the fact that the first act in flexion is the unlocking of the joint by the rotation of the tibia in an inward direction."—*Manual of Practical Anatomy*, part i., pp. 429, 430.

Now, to give the history of the reasoning process that went on in my mind, although it is true, as Goodsir and Meyer showed, that the first motion of flexion is an unscrewing of the knee-joint which the last movement of extension screwed home or locked; and although it is also true that the human body is a high-pressure engine working at a low pressure with great reserve power for emergencies; yet the theory that such an overbalance of power is applied on one aspect of the leg for the purpose of overcoming such small resistance seems a breach of the logical law of parsimony. And the doubt thereby raised of the truth of this explanation became more established when I considered, what any one can easily determine by a simple experiment, that in walking the knee-joint is not locked and unlocked as a necessary part of the act of progression. Some people do lock one or both of their knee-joints in walking, but the movement is not elegant, and it does not appear to give either strength to the limb or comfort to the individual. And although, as I shall show, the knee *may* be locked at either or both of two positions of the step, the muscular power necessary to unlock the joint must be very small indeed. What, then, is the explanation of the proponderance of muscles inserted into the inner aspect of the leg? In other words, with what other muscular action can we correlate this, and so give some more comprehensive and rational explanation of it?

On the assumption that one that puts up a notice, "No road this way," confers almost as great a benefit as one that points the road to truth, I might refrain from saying more on the subject in case I be tempted to go astray by the hypothesis I am about to propound. But it is only right to give a hypothesis a chance of being criticised and tested; so I venture to offer the following contribution to the subject of the muscular mechanism of walking.

In walking, and also in running, the knee-joint is kept slightly flexed, just short of being locked. In this position there must be some contrivance whereby rotation of the tibia on the femur is prevented, since such rotation is possible when the joint is not locked. This contrivance is found in the action of certain muscles, viz.—(1), the long head of the biceps and the semitendinosus, which, arising from the same place, proceed to and are inserted into opposite sides of the leg; (2), the gastrocnemius, which acts from one point below and is attached to opposite sides of the femur above; (3), two short muscles, the short head of the biceps, and the popliteus, which act in concert towards the same end. All these muscles, by their combined action, tend to flex the leg upon the thigh; at the same time they so balance one another as to prevent rotation of the tibia upon the femur; and they also pull upon the tibia and femur in such a manner as to cause considerable pressure on the articular surfaces of these bones. The result of this action is to make the thigh and leg very much a rigid pillar, so far as regards rotation.

Now, to consider the muscles inserted on the inner aspect of the leg. The movement of walking, so far as concerns the muscles I am dealing with, may be regarded as consisting essentially of an extension of the thigh upon the trunk, an action that tends to extend the knee; but this tendency is resisted by the action of the flexors of the knee-joint; so that one may say that the movement of propulsion consists in extending the hip-joint and flexing the knee. The gluteus maximus is the great extensor of the thigh upon the trunk, and in producing extension it tends to straighten the knee; at the same time it tends to rotate the thigh and leg as a whole outwards,

being inserted into the femur, and also, by means of the ilio-tibial band, into the outer aspect of the tibia. When the gluteus maximus contracts, the long head of the biceps and the semi-tendinosus and semimembranosus also contract and help the gluteus in extending the thigh upon the trunk, but resist the action of that muscle so far as regards the extension of the knee; at the same time, the semitendinosus and semimem-branosus counteract the tendency of the gluteus and biceps to rotate the limb outwards. The gracilis and sartorius, so far as they come into action, would assist in keeping the knee-joint flexed, and would, at the same time, tend to rotate the limb inwards. Now, such rotation would be prevented by the action of the external rotators of the thigh at the hip-joint, and it is probable that herein lies the explanation of the great prepon-derance of power on the part of the external compared with the internal rotators of the thigh, a matter which is inexplicable on any other known hypothesis.

To state the matter briefly, I would say, then, that in pro-pelling the body forwards, as in ordinary running and walking, the tibia is prevented from rotating on the femur, and is flexed on the femur by certain muscles acting in pairs, while the flexors inserted into the inner aspect of the tibia, considered as a whole, act in concert with the great extensor and the external rotators of the femur in extending the hip-joint, and in flexing the knee, and in preventing rotation of the limb as a whole.

One or two points demand notice. With reference to the commonly received theory, I wish to point out that it is possible that the knee may be fully extended and locked just at the moment when the limb is leaving the ground to take the pen-dulum-swing forwards; but if it is, the flexors inserted into the inner aspect of the leg have little if anything to do with the action of unlocking, which may be accomplished by a very slight muscular action. Again, the joint may be locked just when the advancing foot has touched the ground; but if it is (and I doubt the fact in the case of ordinary walking), the rolling forwards of the body over the top of this limb by the propelling act of the other obviates any great muscular force being re-quired to undo the locking of the joint.

In this connection a series of careful observations on points like the following would prove useful:—The condition of the various muscles of the thigh at some considerable interval of time after excision of the knee-joint; the effect of tenotomy of the muscles of the ham; the source of the nerve supply of the various muscles that may act in concert in producing certain movements of the thigh. These are points that I can do no more than refer to in this very general statement. But I may point out that many combinations of muscles capable of easy demonstration are generally quite overlooked in discussing the movements of the hip and knee joints. For example, if, in the sitting posture, the thigh is flexed from a right angle to an acute angle with the trunk, a movement effected by the rectus femoris and the ilio-psoas, it will be found that the semimembranosus comes into play. If the action of the semimembranosus is not antagonistic to the outward rotating action of the ilio-psoas it is very difficult to explain what its action in this connection is. Again, in the act of walking with persistently locked knee, or in cases where the leg is jerked forwards and the knee is locked before the foot touches the ground, as practised by some professional walkers and others, the whole power of the biceps, semimembranosus, and semitendinosus is exerted in extending the thigh, while the gracilis and sartorius are exerted in flexing it; and here, I believe, one finds the true economy of the locking apparatus of the knee-joint. But these are subjects on which I cannot enter at present. My point will have been gained if I have succeeded in directing attention to the broad features presented by the muscular mechanism of the thigh and leg employed in progression by walking.

OBSERVATIONS UPON A MASTITIS BACILLUS.

By Allan Macfadyen, M.D. (Ed.).

In the *Agricultural Year-Book of Switzerland* for 1888, Professor Hess, of Berne, published the results of an inquiry into the causes of mastitis in cows. He proved that the infectious forms of mastitis are due to several and distinct kinds of bacteria, which penetrate through the milk canals into the milk glands. Within the latter they find a soil suitable for their growth, and for the development of their specific pathogenic properties. The resulting inflammation of the tissues is at times so mild, and the alterations in the secretion so slight, that the affected cows can still be milked, and the milk used for domestic purposes or for the manufacture of cheese. The milk from one affected cow, by being mixed with milk from healthy cows, can infect large quantities with the active bacteria. The determination of the nature and the action of these bacteria is, therefore, of hygienic and economic importance.

On the suggestion of Professor von Nencki, I undertook the investigation of the chemical products of one of these specific bacteria. In the first place, its causal relation to the disease had to be established. This I was able to do through the kindness and with the assistance of Professor Guillebeau, Berne. A cow suffering from mastitis was slaughtered, and cultures made from the contents of the udder immediately after death. A micro-organism was isolated in pure culture and handed over to me for investigation. It was a short rod bacillus with rounded ends, though occasionally forms were present closely resembling micrococci. Its average length was 1μ. In gelatine stabcultures it formed a dull white growth along the line of inoculation. On the surface the growth was abundant, greyish white, and with an irregular margin. The surface growth adhered firmly to the gelatine, and was viscous. Portions removed with a platinum needle could be drawn out into long threads. In old cultures the superficial growth was meshed and netlike. The bacillus did not liquefy gelatine. It grew

well on the usual culture media, and was easily recognisable by its microscopic appearance and its characteristic growth in gelatine.

Its specific pathogenic properties were proved by the following experiment made on a healthy goat. The goat is well adapted for such experiments, as fluids can be injected into its udder with ease and certainty:—

Five drops of a pure broth culture of the bacillus were injected into each teat. On the day after the injection the animal ate less than usual, and had shivering attacks. The udder was enlarged, firmer, and hot. Milking gave pain, and the milk was ropey and viscous—after twenty-four hours, curdy. The animal, in walking, stretched the hind legs wide apart, as contact with the inflamed udder was painful. In one of the milk-glands there was a considerable quantity of gas. After the third day the symptoms began to diminish, and on the eighth day the inflammation had subsided. Samples of the milk were taken, and gelatine plates inoculated from them. They yielded pure cultures of the bacillus.

It is important to notice that when a natural infection takes place in the stall, the first sign of the inflammatory process is given by the milk itself. The milk contains small coagula before the symptoms of udder inflammation appear. After the inflammation has subsided it is some time before the milk acquires its normal properties. During the inflammation the milk has an acid reaction, is curdy, and contains an increased amount of inorganic matter. The amount of milk-sugar is greatly lessened. The amount of fat is also lessened. The bacteria can also be found in the milk during this period.

Having proved the pathogenic nature of the bacillus, and its causal relation to the mastitis, its action upon carbohydrates, proteids, and fats was tested.

1. *Carbohydrates.*

To 2 litres of beef-broth were added 100 grammes grape-sugar and 50 grammes carbonate of lime. The fluid was sterilised in an autoclave at 120° C., and then inoculated from a pure culture of the bacillus. The air in the flask was replaced

by carbonic acid gas, and the flask placed in an incubator at 38° C. After twenty-four hours there was an active development of gas, and the fluid was frothy. On the third day the first gas samples were collected in an eudiometer tube over mercury. The result of the gas analyses was as follows:—

2 *Litres 5 per cent. Grape-sugar Solution in* CO_2.

	3rd Day. Active Development of Gas.	5th Day. Weaker Development of Gas.	14th Day. Fermentation nearly ended (about 100 cc. Gas in 24 hours).
Reduced Volume.			
Amount of Gas, .	cc. 51·359	cc. 37·04	cc. 49·36
After adding Potash,	11·99	5·94	0·37
After adding Oxygen,	59·263	20·94	5·42
After Explosion, .	41·00	12·15	4·90
After adding once more Potash, .	41·01	12·15	4·89
Result in percentage Volume.			
CO_2, . . .	76·65	83·96	99·25
H, . . .	23·68	16·00	0·72

The gases were, therefore, CO_2 and hydrogen, the latter in decreasing amount. At the beginning of the fermentation more than one-third of the gas was hydrogen; after five days, one-fifth; and after fourteen days, only 0·72 of the percentage

volume, whilst the amount of CO_2 was 99·25 per cent. Methan gas was not present.

Ærobic cultures were also made in sugar broth. In both cases the fluid was examined on the 20th day, and the purity of the cultures tested. In each case some unchanged sugar was present. The fluid was tested with Fehling's solution and then examined in Wild's polaristrobometer. Whilst, however, the amount of unchanged sugar in the ærobic cultures was at most 0·5 grm., the amount in the anærobic was 38·1 grm. In the ærobic flasks there was always an almost complete fermentation of the sugar. The bacillus was facultative anærobic, and like the yeast was most active with a limited supply of atmospheric oxygen.

A portion of the fluid, tested with iodine and caustic soda, gave a distinct precipitate of iodoform. The entire fluid was therefore distilled till no further reaction was given with iodine and soda. The distillate was again distilled down to half its volume, and the process repeated after adding sodic chloride. The final distillate was saturated with carbonate of potash. A thin yellow layer of alcohol collected on the surface. The amount was small and was just sufficient for fractional distillation. It distilled between 74° and 80° C. The odour and the test with benzoylchloride and potash proved it to be ethyl-alcohol. Higher boiling alcohols were not present.

Oxalic acid was added to the remainder in the retort, and then distilled. The distillate contained the volatile fatty acids. It was saturated with ammonia, and concentrated on the water-bath till all smell of ammonia had disappeared. A portion treated with alcohol and sulphuric acid developed the characteristic odour of acetic ether. The entire fluid was precipitated with nitrate of silver, quickly filtered, and the precipitate dried in a dessicator in the dark. The salt was acetate of silver, according to the following analysis:—0·079 grm. of the silver salt gave on combustion 0·051 grm. = 64·55 per cent. silver. The volatile acid was therefore acetic acid.

The remainder in the retort was concentrated and extracted with ether. After distilling off the ether a yellow syrupy fluid remained, which was diluted with water and boiled with

zinc-hydroxide. On analysis it proved to be lactic acid. 0·63 grm. of the salt dried at 110° C., lost 0·0476 grm. in weight = 18·1 per cent., and 0·2154 grm. of the dried salt gave on combustion 0·072 grm. ZnO = 26·84 per cent. Zn.

It was, therefore, the inactive ethylidene-lactic acid $(C_3H_5O_3)_2Zn + 3\ H_2O$—which, as zinc salt, contains 18, 18 per cent. water of crystallisation and 26·75 per cent. Zn.

The ærobic and anærobic cultures gave the same decomposition products.

I may mention here that the bacillus also decomposes glycerine, with and without atmospheric oxygen. The fermentation was accompanied by an active development of gas which lasted fourteen days.

The decomposition products of sugar are—(1) Inactive lactic acid as chief product; (2) acetic acid; (3) ethylalcohol; (4) gases, CO_2 and hydrogen—the latter in constantly decreasing amount.

2. *Fat.*

To 1 litre neutral meat broth was added 2 per cent. of fat, then sterilised and inoculated with the mastitis bacillus. After a month the fluid was tested by Hofman's method. The results were negative—the fat remained undecomposed.

3. *Proteids.*

Two litres of water were added to 500 grm. finely minced meat—the whole sterilised and inoculated with the bacillus. The air was replaced by CO_2. An eudiometer tube was attached to collect the gases. No gas developed, and there was no evident decomposition of the albumen. The ærobic cultures also gave negative results.

Filtered bouillon cultures of the bacillus proved harmless to animals, and the bacillus subcutaneously injected, produced no pathogenic effect. The bacillus, therefore, belongs to the large class of bacteria which requires a soil containing carbohydrates for the full development of their ferment activity. In the milk the sugar is split up by it, and alcohol, acetic and lactic acids result. The acids, and especially acetic acid, by irritating the glandular tissue, probably give rise to the strictly localised inflammation of the udder. The first condition for the inflam-

mation is a chemical change in the milk itself—which is brought about by the bacteria—with the formation of the above-mentioned products.

This bacillus is also a cause of *boursouflement des fromages*, an abnormal fermentation which lessens greatly the market value of Swiss cheese. I refer here to the cheeses made in the Emmenthal near Berne.

The following experiment was made in Dr Freudenreich's laboratory. Control cheeses, made from 10 litres of milk, were inoculated from a pure culture of the bacillus, at the moment when the rennet was added, and kept at the usual temperature, viz. 16° C. A control uninoculated cheese was made at the same time. (The cheese contains about 2·5 per cent. milk sugar.)

The inoculated cheeses became full of large holes and diminished in weight; the uninoculated cheese presented a normal appearance.

At times these abnormal fermentations give rise to an inflammable gas, which, according to my gas analyses is Hydrogen.

I finally tested the effect of the abnormal milk upon animals.

Flasks containing 1 to 2 litres milk were sterilised, inoculated with the mastitis bacillus and kept at 38° C.; uninoculated milk served as control. The milk was inoculated in the evening. Next morning there was an active development of gas, and the milk was frothy. In eighteen to twenty hours the milk contained coagula, and in twenty-two to twenty-six hours the coagulation was complete. The control milk was unchanged. The reaction of the milk was always markedly acid. At the ordinary room temperature, the coagulation was slower, and only complete after four to five days. The optimum temperature was 37° to 38° C. This is probably due to the fact observed by Warington (*Lancet*, 1888, vol. i.), that the quantity of acid necessary to coagulate milk is smaller the higher the temperature.

An adult dog—15 kilogrm.—was fed with the fermented milk. The result was negative. The milk was then mixed with soda to neutralise the acid of the gastric juice, but again with negative results. On the other hand, kittens fed with the milk had violent attacks of diarrhœa. After one to two days they recovered. Thus, whilst the milk had no injurious effect

on the adult dog, for the kittens it was always injurious and produced diarrhœa.

Milk from cows infected with this bacillus might therefore easily cause diarrhœa in children.

The bacillus grows well in gelatine containing 2 per cent. bile, and also in sterilised ox bile, a factor which would favour its growth and development in the intestine.

The above researches prove that this bacillus can produce:—

1. An inflammation in the udder of cows.
2. An abnormal milk secretion.
3. An abnormal fermentation of cheese.
4. Diarrhœa in young animals, and may therefore be a possible cause of diarrhœa in children.

The bacillus retains its vitality for a long time—after six months the cultures still retained their ferment activity.

The bacillus is probably only one of a large class of bacteria capable of producing mastitis. It would be interesting to investigate in what way other bacteria capable of producing this disease act. Is the inflammation due more to their fermentative activity than to any distinct pathogenic properties of the cells themselves? Bacteriological chemical investigations would not only decide this—they would at the same time aid us in distinguishing physiologically micro-organisms which often closely resemble one another morphologically.[1]

[1] It is a pleasant duty to acknowledge here my great indebtedness to Professor von Nencki for the invaluable advice and help so ungrudgingly given in this and other work carried out in his laboratory.

ON THE MINUTE ANATOMY OF THE PES HIPPOCAMPI, by Dr LUIGI SALA,[1] *and* ON SOME GENERAL ANATOMICAL FACTS BROUGHT OUT BY GOLGI'S METHOD. Abstract by WILLIAM ALDREN TURNER, M.B. (Edin.), M.R.C.P. (Lond.)

THE work under review deals with the minute anatomy of the pes hippocampi elucidated by Golgi's method. The method shows that the structure of this portion of the brain is not so complicated as one would imagine from the descriptions of Kupffer, Meynert, Huguenin, Krause, and others. Previous to Golgi's original observations upon this region, it was generally believed that a half, one, or two convolutions took part in its formation. Duval, who supported the latter view, demonstrated that the inner margin of the fimbria was not free, but was continued into a delicate layer (the ventricular layer of the fœtus or the ependyma in adults), which enveloped the choroid plexus in a kind of mesenterial fold, and completely closed in the lateral ventricle. According to this view it was believed that of the whole formation of the cornu ammonis only one part—the inner —belonged to the brain surface, and was formed from the gyrus hippocampi and the fascia dentata, while the other, or outer part, lay in the lateral ventricle. Golgi, by means of his silver method, concluded that the collective hippocampal formation consisted of two perfectly distinct convolutions, which were microscopically revealed by two distinct types of cells, one of which was represented in the grey convoluted layer, the other in the fascia dentata. On the other hand, there is the view of Giacomini, that the pes hippocampi represents no convolutions, but a specially modified portion of the brain cortex. He bases his belief on the fact that the pes may, in several animals in which no trace of convolution exists, reach a considerable development.

Golgi divides the pes hippocampi into the four following layers:—

1. The inner or first layer of nerve fibres (alveus).
2. The grey convoluted layer, or layer of large ganglion cells.
3. The outer or second layer of nerve fibres (lamina nuclearis).
4. The layer of small ganglion cells (fascia dentata). Sala's description is based upon these four layers.

[1] The original work is to be found in *Zeitschrift für Wissenschaftliche Zoologie*, Bd. 52, Hft. 1, s. 18. The method adopted was the long one proposed by Golgi: Harden tissue for 20–30 days in 2 per cent. bichromate of potassium, and then place in ·75 per cent. nitrate of silver. Golgi's short method is: Harden for 4–5 days in 2 per cent. bichromate of potassium, then for 24–30 hours in 1 per cent. osmic acid (2 parts), and 2 per cent. bichromate (8 parts). Remove and place in ·75 per cent. silver nitrate solution.

1. *The Alveus.*—This consists of a layer of thin medullated nerve-fibres running parallel to each other, and forming a bundle which covers the whole cornu ammonis. The fibres arise from the large cells of the second layer, from the small cells of the fascia dentata, and from the cells of the gyrus hippocampi. Numerous glia cells are scattered among the fibres, and here, as elsewhere, they are attached by their processes to the walls of the blood-vessels. In addition, a few nerve-cells have been found, whose axis-cylinder process finds its way into the subjacent grey layer. Golgi believed that these cells partly belonged to the grey layer. The alveus is in relation on its free surface with the cells of the ependyma ventriculorum. The bodies of these cells are continued into the alveus by a long process, which, contrary to previous belief, divides shortly after its origin into numerous branches that are attached to the blood-vessel walls and to the glia cells already mentioned, while others lose themselves in the nerve substance, apparently passing as far as the large pyramidal cell layer.

2. *The Grey Convoluted Layer.*—In addition to the characteristic cells of this layer, numerous medullated nerve-fibres are present. They consist of fibres which arise from the lamina nuclearis, and are in transit through this layer on their way to the alveus and the fimbria, and partly also of fibres which pass from the fascia dentata to the alveus. Medullated fibres are also present where this layer bounds the lamina nuclearis. The cells of the layer are pyramidal, and are continued inwards by a protoplasmic process which, dividing and subdividing, ends at the numerous glia cells scattered throughout the layer, but especially in its deeper parts near the lamina nuclearis. Filaments from these processes pass through the alveus to fuse with the cells of the ependyma. The cells occupy one or more rows near the outer limit of the layer. The nerve-process passes off from the side next the alveus into which it goes; a short distance from the body it gives off filaments, which form a delicate network in the grey layer. From this there can be traced many fibrils which go on the one hand into the alveus, on the other into the next layer.

3. *Lamina Nuclearis.*—This consists of medullated nerve-fibres arising similarly to those of the alveus. Running parallel to the grey layer, they turn backwards with this layer and are continued behind into the white matter, which covers the subiculum and gyrus hippocampi.

4. *Fascia Dentata.*—Of this there are two layers, which must be separately considered—a superficial, formed of medullated nerve fibres, and a deep one, composed of the characteristic cells and their processes.

(*a*) The superficial white layer of the fascia dentata consists of fibres similar to those of the alveus and the lamina nuclearis. It commences in a series of medullated fibrils, running together to form a bundle, which is most evident where the fascia dentata is folded backwards; further on it is lost in the superficial white bundle of the lamina nuclearis. Although closely associated, these two layers can be separated by the presence of numerous blood-vessels which lie

between them. The fibres arise mainly from the small spherical cells of the region, and to a less degree from the large pyramidal cells.

In the part of the fascia dentata which remains uncovered, one readily sees that the superficial white layer is not at the periphery of the fascia itself, but that between this and the bundle there is a thin layer which contains no nerve-fibres. This is at the place where the fascia is in relation with the subiculum cornu ammonis. Golgi's method shows that this area is very rich in neuroglia cells, in which many of the protoplasmic processes of the small spherical cells end. It contains also a few nerve-cells, whose nerve-processes are lost in numerous fine branches.

(*b*) The characteristic cells of the fascia dentata are small and spherical, or oval in shape. They lie in the deeper parts of the layer, where they usually form a single row. They present a great likeness to Purkinjé's cells—*i.e.*, from one side there spring the protoplasmic processes, from the other the single nerve-process. The former, five or six in number, branch dichotomously, and, passing through the white layer, reach the neuroglia cells already described. The nerve-fibre process gives off lateral branches, which in their turn divide, and so come to form a delicate network which exists throughout the whole course of the fascia dentata. From this network numerous secondary processes arise, which are continued as nerve fibres (type 2), but the axis-cylinder process can also be traced in many cases through the network without losing its individuality (type 1). From this network these fibres pass away to take part in the formation of the alveus and the fimbria, and to a less degree in the lamina nuclearis and superficial white layer. As long as the fibres are in the network they remain non-medullated, and possess peculiar triangular and oval swellings.

In the network a considerable number of neuroglia cells are found, as well as isolated nerve-cells. These latter are present mainly in the outer peripheral part of the net, and possess protoplasmic and nerve processes. It is probable that these cells belong to the terminal portion of the grey convoluted layer.

Some General Anatomical Facts brought out by Golgi's Method.

1. Of the many processes which a nerve-cell gives off, only one—the axis-cylinder process—is in direct relation with a nerve-fibre; the others—protoplasmic processes—mainly subserve the nutrition of the nerve elements through a direct relationship with neuroglia cells and blood-vessels.

2. The axis-cylinder process is related to nerve-fibres in one of two ways:—(*a*) In the first, or motor type, this process passes directly into a nerve-fibre in spite of lateral ramification. (*b*) In the second, or sensory type, a network of nerve fibrils intervenes between the cell and the nerve-fibre.

3. The protoplasmic processes are neither continuous with nerve

fibres nor anastomose with them. They probably functionate by contact with other such processes, and so conduct from cell to cell. The following facts support the belief that the protoplasmic processes are essentially of a "nervous" nature (Kölliker). (*a*) In structure and chemical constitution they are similar to the axis-cylinder process of nerve-cells. (*b*) It is not uncommon for a nerve-process to arise from protoplasmic processes.

4. Continuity of structure is not essential for the propagation of nerve impulses. Cells and fibres may functionate by contact only. This is probably the most important fact yet pointed out from the study of the nerve elements by this method. Kölliker has shown that this occurs in the following situations :—(*a*) In the sensory root fibres, which end free in the grey matter of the cord and medulla. (*b*) At the terminations of the lateral branches of the nerve process of many of the cells of the grey matter. (*c*) At the terminations of the longitudinal fibres and collaterals of the anterior and lateral pyramidal tracts in the grey matter of the anterior horns.

It is, therefore, apparent from these observations that the three most important functions of the spinal cord, the propagation of motor, sensory, and reflex action, takes place not by a direct continuation of nerve structures, but by mere contact of nerve-cells, nerve-fibres, and their processes.

DIE ENTSTEHUNG DER WINDUNGEN DES GROSSHIRNS (The Origin of the Cerebral Convolutions). By Dr F. Schnopfhagen of Linz. (*Jahrbücher für Psychiatrie*, ix. 3, s. 197).

The author's object in this communication is to show (in opposition to the view usually held that the conformation of the brain is due to the influence of the enveloping skull cap), that it derives its form from the growth of the tissue between the cortex and the basal ganglia.

After considering in detail the fibres of the Insula Reilii and its relations to the other fibre systems of the cerebral hemispheres, he relates the action which the fibres of the corona radiata and the fibres issuing from the nucleus caudatus, corpus striatum, and optic thalamus have upon the formation of the cortex. This great mass of fibres goes on radiating towards the cortex and extending outwards, since the ganglia at the base cannot give way. He submits that the gyri correspond to the projection system of fibres, and the sulci to the association fibres, and that this separation takes place in embryo brains which are still without their convolutions. The work is concluded with a summary, which gives the author's views in a short and concise form. "The growth of the projection fibres raises the cortical

region in the direction in which they irradiate from the ganglia of the base, and so form those prominent strands which go by the name of convolutions. This fibre system further indicates the greatest amount of growing energy of the brain mantle, because it can only elongate on one side, and that is towards the cortex. The sulci arise along the lines of least growth energy, that is, where the division points of the association fibres range together in lines. The extensive sphere of the furrow walls affords the different long association fibres sufficient playroom to assist in the building up of the convolutions"

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PROCEEDINGS OF THE
ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

NOVEMBER 1890.

THE FOURTH ANNUAL GENERAL MEETING was held at Charing Cross Hospital School Buildings, on November 26, 1890. Professor HUMPHRY in the chair. Present twenty-eight members and visitors.

Dr George Gulliver and Mr C. H. Abbott were elected members of the Society. The following gentlemen were nominated for election:—Mr Percy Dean, Demonstrator of Anatomy at the London Hospital; Professor Anderson Stuart of the University of Sydney; Dr Herbert Waterhouse, Demonstrator of Anatomy at Charing Cross Hospital; and Mr Percival M'Leod Yearsley, Demonstrator of Anatomy at the Westminster Hospital. The following gentlemen were then elected as officers for the ensuing year:—*President*—Sir W. Turner, F.R.S.; *Vice-Presidents*—D. J. Cunningham, M.D., Alexander Macalister, F.R.S., G. D. Thane; *Treasurer*—G. B. Howes; *Secretaries*—Ambrose Birmingham, M.D. (*Ireland*), W. P. Herringham, M.D. (*England*), J. Yule Mackay, M.D. (*Scotland*); *Council*—Wm. Anderson, H. St John Brooks, M.D., Stanley Boyd, W. H. H. Bennett, John T. Charles, M.D., John Cleland, M.D., F.R.S., John Curnow, M.D., Wardrop Griffith, M.D., David Hepburn, M.D., C. B. Lockwood, Clement Lucas, A. M. Paterson, M.D., R. W. Reid, M.D., Charles Stewart, J. Bland Sutton, Johnson Symington, M.D., Arthur Thomson, M.B., Frederick Treves, Bertram Windle, M.D., Alfred H. Young, M.B.

The following resolution was then proposed from the chair and carried unanimously.

"That the following be made a Rule of the Society:—

"Rule 22.—The Council are empowered to nominate a limited number of persons who have distinguished themselves in promoting the science of anatomy, for election as Honorary Members of the Society. The election shall take place at an Annual Meeting, and a list of the nominations shall be sent to each Member with the notice of the Meeting."

The TREASURER then made a statement of accounts showing a balance of £7, 13s. 0d. in favour of the Society.

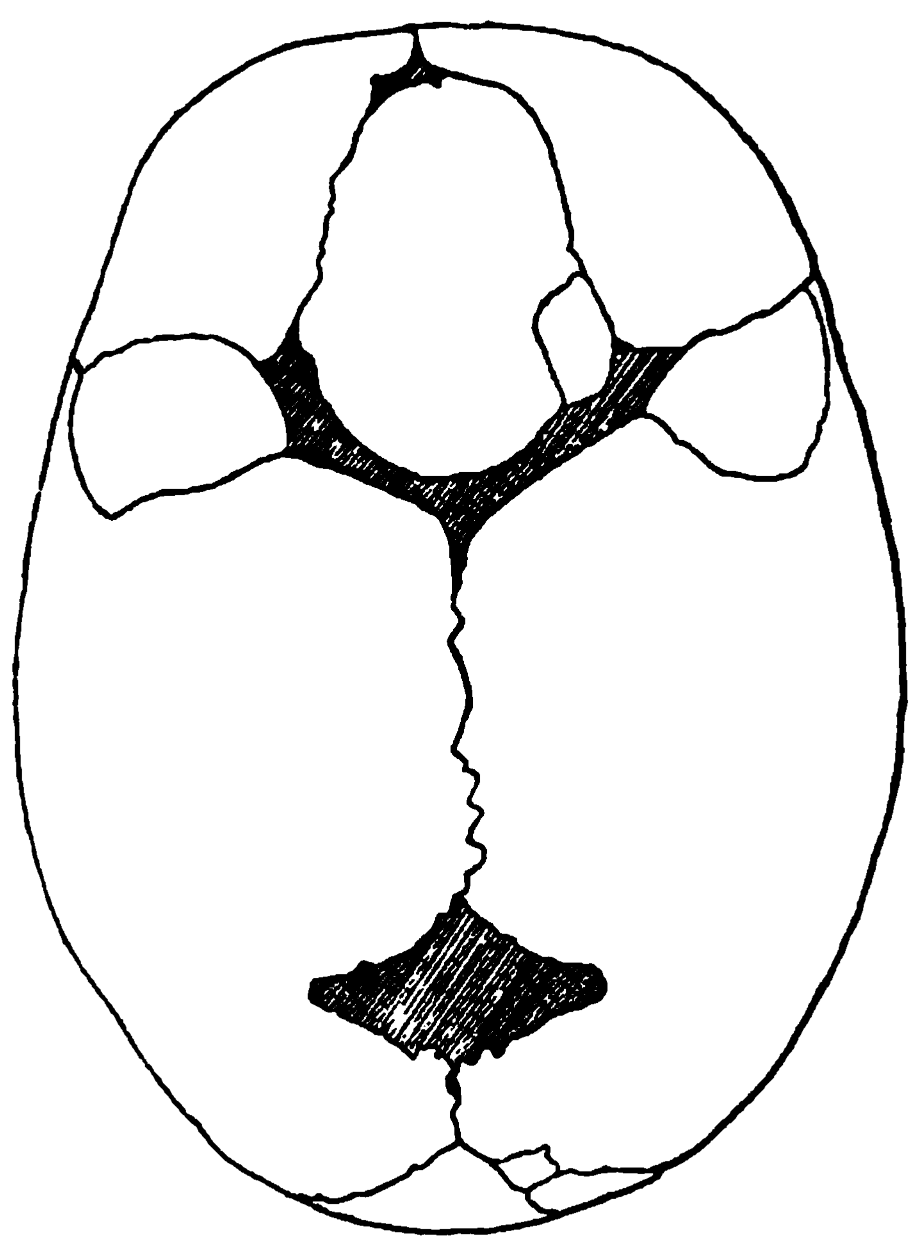
Professor HUMPHRY, then vacating the chair, made a short farewell speech to the Society.

A vote of thanks to the retiring President was proposed by Professor THANE seconded by Professor MACALISTER, and carried unanimously.

Professor HUMPHRY resumed the chair by request for the remainder of the meeting.

The following papers and specimens were then brought before the Society :—

Dr G. GULLIVER showed a *Skull with Wormian Bones in the Frontal Suture.* The specimen is the calvaria of the skull of a child aged four months. In the anterior fontanelle is a large rhomboidal median ossification, filling up the whole space except at the upper part, where a narrow margin of membrane is left. Extending



out into the frontal suture from this membranous margin of the fontanelle there is on each side a large bony plate, the two varying so little in size and extent that they may fairly be described as symmetrical. As matters of less importance it may be noted that there is a separate ossification in the occipito-parietal sutures, and that the sagittal fontanelle persists.

Bones in the situation of these appear to have been described under the names of Wormian bones, anterior fontanelle bones, and

more recently as interfrontal bones by Howes, who, in common with Humphry and Hyrtl, says they are of rare occurrence.

Such bones cannot, of course, be due to arrest of development, like the interparietal bone when found in man, though possibly they may be regarded as evidence of reversion towards ancestral types such as the Ganoid fishes, where we find median and lateral rows of bony plates throughout the body.

It is interesting to note that the child was the subject of much congenital deformity—hare-lip, cleft palate, fissure of the iris and supernumerary auricles.

Professor ALEXANDER MACALISTER exhibited—

1. Egyptian Skulls, one of which showed a ring of bone projecting downwards from the lower surface of the occiput behind the posterior condyloid foramen; another showed on the inner wall of the orbits a junction of the frontal and palate bones behind the ethmoid plate.

2. Specimens illustrating (*a*) the cervical fascia near the base of the skull, (*b*) muscular and vascular anomalies, (*c*) new methods of preservation and exhibition.

Professor STEWART demonstrated a section of the *Scalp of an Adult Negro* showing the curved hair follicles.

Mr ARTHUR THOMSON read a paper on *The Skin and Hair of an Negro Fœtus*, which will be found at p. 272 of the January number of the *Journal of Anatomy and Physiology.*

Mr F. G. PARSONS showed two specimens of the *Short Muscles of the Thumb*, lent by Professor Stewart from the Museum of the College of Surgeons. In both of these the deep part of the flexor brevis pollicis or adductor obliquus was inserted into the whole length of the metacarpal bone of the thumb, as well as into the other insertions described in the text-books. This insertion into the metacarpal bone was looked upon as the deep part of the opponens pollicis, as, in one of the specimens, the superficial part could be seen as a distinct thin lamina separated from it in the whole of its course. With a view to determine the constancy of this arrangement eight other hands were dissected, in none of which did the adductor obliquus send any fibres to the metacarpal bone, but in all of them the opponens was easily separable into a thin superficial stratum and a much thicker deep stratum connected either at the origin or insertion with the adductor obliquus. The superficial lamina, moreover, arose from the outermost part of the anterior annular ligament, while the deep part took origin underneath it from the same half of the ligament. Between the two layers a distinct cellular interval was frequently found.

All the preparations showed a distinct muscular slip arising from the front of the lower part of the shaft of the 2nd metacarpal bone at the place where the radial artery crosses it. If the radial artery is to be regarded as the division between the adductor transversus and adductor obliquus, this slip should be considered as part of the

former muscle rising from the 2nd metacarpal bone. If, on the other hand, the slip is looked upon as adductor obliquus, then the radial artery should be described as piercing that muscle.

In most text-books the radial artery is described until it pierces the 1st dorsal interosseous muscle, and is taken up again when it appears in the palm between the adductors transversus and obliquus, but between these two points there is half an inch of artery lying between two layers of muscle, the posterior being adductor transversus or obliquus according to the taste of the describer, and the anterior adductor obliquus.

The slip from the lower part of the 2nd metacarpal is quite distinct from the common origin of the adductor obliquus from the bases of the 2nd and 3rd metacarpals and from the front of the os magnum and trapezoid, but it shows more tendency at its insertion to join the adductor obliquus than transversus; the radial artery should therefore be described as piercing the adductor obliquus after giving off the radialis indicis and finally emerging into the palm between the adductor transversus and obliquus.

Several of the preparations showed the expansions from the short muscles to the extensor secundi internodii tendon. Of these the external is quadrilateral, and is derived from the abductor pollicis entirely, while the internal is triangular with its base attached to the extensor tendon, the apex being a small rounded tendon in which a fasciculus of the adductor obliquus ends. This fasciculus lies in the midst of the muscle, and is surrounded by fibres which are inserted into the metacarpal phalanx of the thumb.

The adductor transversus passes chiefly in front of the adductor obliquus, and contributes few, if any, fibres to the inner expansion.

Mr C. B. Lockwood showed several specimens of *Synostosis of the Vertebræ*. Some were probably due to disease, and consisted in union of the bodies of vertebræ by bridges of bone in the situation of the anterior common ligament, and by ossification of the intervertebral discs. In all of these specimens the outgrowths of bone were eccentric, and did not protrude at all into the spinal canal. In one of the specimens the articular facets of the axis and third cervical vertebræ were firmly synostosed on the right side; and in this case the evidences of disease were absent, suggesting that the fault may have been congenital. In one of the spinal columns in which dorsal vertebræ were synostosed the lamina of the 4th lumbar vertebra was divided by a cleft which ran through it betwixt the superior and inferior articular facets of the right side; the left lamina was intact. This defect seemed to be rather common in the 5th lumbar vertebra and might affect both sides. It was quite inexplicable by reference to ordinary accounts of the ossification of vertebræ.

The Meeting then adjourned.

PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

FEBRUARY 1891.

A Meeting of the Society was held on Monday, February 23, 1891, in the Westminster Hospital School Buildings. Twenty-six members and visitors were present, and Sir W. Turner, the President, took the chair for the first time.

The Minutes of the previous Meeting were read and confirmed. The following gentlemen were elected Members of the Society:—Messrs Percy Dean; Herbert E. Waterhouse; Percival M'Leod Yearsley; and Professor Anderson Stuart. The following were nominated for election:—C. S. Sherrington, M.B., Lecturer on Physiology at St Thomas' Hospital, proposed by G. D. Thane, William Anderson, and W. P. Herringham; A. W. Hughes, M.B., C.M., M.R.C.S., Lecturer on Anatomy at the School of Medicine, Edinburgh, proposed by Johnson Symington, D. J. Cunningham, and W. P. Herringham; and T. W. P. Lawrence, M.B., F.R.C.S., Curator of the Museum at University College, London, proposed by G. D. Thane, Alexander Macalister, and W. P. Herringham.

Professor Macalister showed a series of specimens to illustrate the *Periosteal Ligaments.*

Mr William Anderson showed a Left Clavicle, probably female, presenting a marked *Articular Process in the Region of the Conoid Tubercle,* which must have articulated with the coracoid process. The corresponding scapula was not in his possession. He suggested the possibility of such an anomalous articulation being formed as the result of raising the upper limb to support a weight carried on the head. Reference was made by several speakers to a similar explanation given by Mr Arbuthnot Lane.

Mr Balgarnie showed an abnormal *Ligamentous Radio-Ulnar Band* which stretched from the upper and inner surface of the coronoid process of the ulna to the tubercle of the radius, the outer edge of which it crossed to be inserted at the lower part.

It lay above the insertion of the biceps tendon, and in a direction nearly parallel to the oblique ligament.

Its action was evidently to limit supination.

Dr ANDREWES had seen a similar specimen in which the band was very much larger and stronger than that exhibited.

The Secretary read for Mr ELWORTHY notes of a case presenting *Abnormalities in the Hepatic Artery and the Intestine supplied by it.*

The body was that of a large adult male. The cœliac axis sprang from the aorta in the usual position, and gave off the gastric and splenic arteries, which ran a normal course to their destinations. Two hepatic arteries sprang from the axis. The upper or left hepatic having given off the gastroduodenal, and half an inch further a small pyloric branch, which ran leftwards to the pylorus, entered the left lobe of the liver at the transverse fissure. The gastroduodenal itself also gave off a branch upwards, which divided into four small arteries, one going to the neck of the gall bladder, the rest entering the liver at the transverse fissure. The lower or right hepatic ran to the right, behind the portal vein and common bile-duct, gave a large branch which ran along the gall bladder to its fundus, and then divided into three other large branches which entered the right lobe. A small branch ran from the cœliac axis to the pancreas.

The following abnormalities were noticed in the intestine. The stomach lay wholly to the left of the middle line, the pylorus being on the left side of the vertebral column opposite the first lumbar vertebra, and the first part of the duodenum passed behind the peritoneum to the right side of the second lumbar. Both pylorus and duodenum were close upon the spine, and the latter had no mesentery or freedom of movement. The second part of the duodenum turned downward to the body of the third lumbar vertebra as usual.

The head and tail of the pancreas were normal, but were joined by a small isthmus over the spinal column which was only the breadth of a finger.

There was no pathological condition in this region. It seemed rather as if the obliteration of mesentery, which naturally occurs at the second and third parts of the duodenum, had spread to the first part also, and had tied this down to the posterior abdominal wall.

A further abnormality noted was a peritoneal pouch passing up behind the splenic flexure of the colon, in what would naturally have been the costo-colic ligament, and running for a distance of three inches between the diaphragm and the greater sac of the peritoneum.

Dr HERRINGHAM showed a specimen of *Right Aorta with persistent Left Aortic Root giving Origin to the Left Subclavian.* The heart was normal in position. The aorta passed upwards and to the right, turned backwards to the right side of the trachea and œsophagus, and passed

to the left between the œsophagus and the vertebral column. The position of the thoracic duct was not noted. The branches were given off in the following order: first, the left carotid, which, rising from the left side of the aorta at the first bend, passed upwards to the left in front of the trachea to the root of the neck; second, the right carotid, which, rising close to the left artery, passed vertically upwards; third, the right subclavian, which, given off from the back of the second part of the aorta, a full inch from the origin of the right carotid, passed outwards over the rib as usual. No branches were given off while the artery was crossing the spine. On reaching the left side part of the original left aorta was seen persisting as a blind pouch, about an inch in length, projecting forward from the main trunk at the angle between the transverse and downward parts of its course, and coming to the level of the front wall of the trachea. From the end of this blind pouch on the outer side arose the left subclavian, and on the inner side the ligamentum arteriosum was attached.

The recurrent laryngeal nerve of the right side ran round the right aortic arch; that of the left side was not traced. The aorta had become uniformly dilated, and killed the patient from whom it was taken by compressing the trachea forwards. It had also caused paralysis of the right side of the larynx by pressure on the recurrent laryngeal nerve, which was swollen and adherent to the vessel as it hooked underneath it.

Mr Stanley Boyd showed the plantar half of a *Divided Internal Cuneiform* of the foot.

The Secretary for Professor Windle showed two specimens of the *Stylo-Auricularis Muscle*, and two of a *Ligament* in the same situation, and read the following note thereon:—

"The two specimens of stylo-auricularis muscle were both found in the present winter session, and indeed within two days of one another, which is the more curious since they are the only specimens which I have ever seen. In his *Catalogue of Muscular Anomalies*, Macalister (p. 6) says that he never observed a well-marked instance in any of the subjects, nearly 700 in number, which he had noted. It appears, therefore, that it is an anomalous muscle of extremely rare occurrence. The name which I have used is that which was given to the muscle by Hyrtl, Lauth calling it depressor auriculæ, and Wenzel Gruber describing it as an auricular slip to the stylo-glossus.

"In one of my specimens the muscle is continuous by its tendon of origin with the stylo-glossus, but also arises in part from the styloid process. It is inserted into a spur of cartilage which projects from the lower part of the cartilaginous portion of the external auditory meatus, just where that portion joins the bony canal.

"The second specimen, which came from a different subject, may best be described as arising by a muscular belly from the stylo-glossus. This belly develops a tendon to which a second muscle is connected, which is inserted in the same manner as the last-mentioned specimen.

"On looking up the subject in Macalister's work, I found that he

stated that its place was often occupied by a fibrous cord. I examined the region on both sides in the subject which I happened to be using at the time for lecture purposes, and found this band on both sides. On the one it was poorly marked, but sufficiently definite, especially in the recent state, and lay along the styloid process, passing to the cartilaginous spur already mentioned. On the other, it was exceedingly well-marked and definite, and passed from the stylo-glossus to the same spur."

The PRESIDENT then read a paper on a *Human Cerebrum with remarkably modified Fronto-Parietal Lobe*, which will be found at p. 327 of this volume of the *Journal of Anatomy and Physiology*. The President's opinion, as well as that of other speakers, was that the modification was of pathological origin, and of pathological rather than of morphological importance.

The PRESIDENT then gave the following account of the *Relationship of the Alveolar Form of Cleft Palate to the Incisor Teeth*:—

"In January 1855 I described, in vol. xix. of the *Journal of Anatomy and Physiology*, a series of fifteen casts of the roof of the mouth in cases of cleft palate, which I had examined with reference to the question of the relation of the cleft through the alveolar border of the jaw to the incisor teeth. From an analysis of these specimens, and of forty-nine specimens which had previously been described by Dr Theodore Kölliker, I stated that they might be divided into two groups—one in which a precanine tooth was situated between the canine tooth and the alveolar cleft, and in it were fifty-one specimens; the other consisting of thirteen specimens, in which no precanine tooth was situated between the canine tooth and the cleft. I then discussed the bearing of these observations on the theory promulgated by Dr Albrecht, that in the alveolar form of cleft palate the gap is not, as is usually stated, in the maxillo-intermaxillary suture, but is situated within the intermaxillary bone, which would arise, therefore, from two distinct centres of ossification.

"During the present winter I have had, through the kindness of Mr Bowman Macleod, L.D.S., the Dean of the Edinburgh Dental School, the opportunity of examining the upper jaw of a youth, aged 14, affected with mesial cleft palate and double alveolar clefts, in whom all the permanent teeth, except the wisdoms, had erupted. None of his permanent teeth had been extracted, so that one saw the upper dental arch exactly in the condition which had been produced by the maldevelopment of the upper jaw. A pair of teeth, which from their form were obviously central incisors, were on the mesial side of the double alveolar clefts, in the most anterior part of the jaw, which had been pushed somewhat to the right, so that the right central incisor overlapped the root of the right canine. Two permanent molars, two bicuspids, a canine and a precanine, were on the outer side of each alveolar cleft. Each cleft was therefore situated between the incisor and the precanine tooth of its own side.

"Another case bearing on the same question has also occurred during

the winter in the practice of my colleague, Professor Chiene, to whom I am indebted for the opportunity of examining a cast of the deformity. The patient, a young man aet. 21, had hare-lip, mesial cleft palate, and left alveolar cleft. The permanent teeth were all erupted except the wisdoms, and were present in the upper jaw, the crown of the right lateral incisor having, however, been broken off, so that only a stump was left. On the right side central and lateral incisors had erupted. On the left side the central incisor, which was set obliquely in the intermaxilla, bounded the median side of the cleft, and the lateral side was bounded by a precanine tooth, somewhat smaller than the usual size of a lateral incisor.

"If the precanine teeth in these specimens are to be regarded as incisor teeth—that is, as teeth developed in association with the intermaxillary part of the upper jaw—it would follow that the alveolar cleft in each instance was within the intermaxillary bone, and not in the suture between it and the superior maxilla; whilst the precanine tooth would be the outermost incisor.

"These specimens, therefore, so far as we can base the argument on the position of the incisor teeth, support the view that the alveolar cleft is within the intermaxillary bone, and not in relation to its lateral border."

Professor CURNOW remarked that this was the best explanation of some of the numerous specimens of premaxillary bones removed by Sir William Ferguson from cases of alveolar cleft palate, and placed in the Museum of King's College, London.

Professor D. J. CUNNINGHAM exhibited the Skull and some of the other bones of the *Skeleton of the Irish Giant*, Cornelius Magrath. He stated that for 131 years this skeleton had been preserved in the Trinity College Museum, Dublin. It measured 7 ft. 2¼ in. in height, and the condition of the skull was such that he was led to believe that Magrath had suffered during life from acromegaly. The face (more particularly the mandibular part), was large in proportion to the cranium, and the pituitary fossa was enormously expanded. Indeed, the sphenoidal air-sinus was completely obliterated, and there was a perforation right through the base of the skull, which was only closed below by the vomer. Further, there were signs which seemed to indicate that the enlarged pituitary body had extended into the right orbital cavity through the sphenoidal fissure.

Dr Cunningham considered the case to be one of interest, because it seemed to show some connection between general giant-growth and acromegaly, and he referred to Langer's observation, that in men of gigantic growth the pituitary fossa is usually expanded. He had examined the skeleton of Byrne, the giant, in the College of Surgeons Museum, and had noticed many points in which it resembled Magrath's skeleton. He was particularly interested to find in the skull a distinct expansion of the pituitary fossa.

Dr Cunningham objected to the term "acromegaly," and stated that

his classical friends in Dublin had suggested the much more correct term of "megalacria" for the disease.

The PRESIDENT referred to the strong resemblance between the appearance of the skull of Magrath and that of a specimen in the Anatomical Museum of the University of Edinburgh, photographs of which he exhibited, which was described by Dr Alexis Thomson in the *Journal of Anatomy and Physiology*, July 1890.

Mr A. S. GRÜNBAUM showed an *Anomalous 6th and 7th Cervical Vertebræ* (see fig.), and read the following note thereon:—

"This is an instance of non-union of the costal process of the 7th cervical vertebra with the body and transverse process, being joined, however, to the costal process of the 6th cervical vertebra by a bar of bone; all three portions being perfectly continuous and united.

"There are two articular surfaces on the 7th vertebra for costal process: one on the body of the vertebra is smooth, and directed backwards and outwards; the other, on the lower edge of the anterior surface of transverse process, just internal to the tubercle of the transverse process, is rough,—to form a synchondrosis,—and directed downwards and inwards. The surfaces on the detached costal process correspond, and are, of course, directed in the opposite direction. In the 7th cervical vertebra, the costal process and the bony lamella connecting it with the transverse process pass insensibly into one another; the detached portion in this case, as would be expected, involves both.

"The bar of bone joining this with the costal process of the 6th descends from the tubercle of the latter—less prominent than ordi-

narily in this case—going slightly outwards and becoming slightly flattened and broader as it descends to fuse with the process of the 7th. It thus divides the entrance to the intervertebral foramen into two parts—an anterior and a lateral portion, the former being obviously for the vertebral artery, and the latter for the nerve.

"The ossified portion between the two vertebræ evidently corresponds to the anterior superior costo-transverse process."

Mr A. S. Grünbaum then showed *Two Cases of Excavations in the Skull due to Dilatations on Lateral Sinus.*

On the first skull in which this was observed the left jugular fossa, viewed from below, appeared elongated backwards and divided into two portions by a thin bridge of bone running transversely across it. Viewed from the inside, however, it was seen that the orifice was narrower below than above, and had probably nothing to do with the jugular foramen. It seems to have arisen from a varicosity or dilatation at the lower end of the lateral sinus, which first pitted and then perforated the bone. The lamella of bone which thus remains forming the posterior wall of the jugular bulla is convex towards the latter, with rather sharp edges. The opening is oval in shape, and 10 mm. long by 4 mm. broad, and the depth of the canal formed, 10 mm. The groove for the lateral sinus is well marked, and the bones of the skull altogether rather thinner than normal.

In a second specimen the perforation had not actually taken place; but a fossa with exceedingly thin floor existed in precisely the same position on the right side. In this case, too, the groove for the right lateral sinus was extremely well marked. The depth of the fossa was 7 mm.

Mr Grünbaum then demonstrated some points in the *Anatomy of the Sub-occipital Region*, an account of which will be found at p. 428 of this volume of the *Journal of Anatomy and Physiology.*

Professor D. J. Cunningham then showed several specimens of Human Fœtal Brains, ranging from the fourth up to the eighth month, showing that the three radial "primärfurchen" of Bischoff and Pansch are repeated upon the surface of the *insula*, and form these three sulci, which correspond in their later development to the sulcus præcentralis, the fissure of Rolando, and the sulcus post-centralis of the cerebral mantle. This subject is discussed more fully by the author in a paper on the *Island of Reil* in the April number of the *Journal of Anatomy and Physiology*, p. 378.

The meeting then adjourned.

PROCEEDINGS OF THE ANATOMICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

MAY 1891.

A MEETING of the Society was held on Monday, May 25, 1891, at University College, London.

The President, Sir WILLIAM TURNER, took the chair. Twenty-one members and visitors were present.

The minutes of the previous meeting were read and confirmed.

The following gentlemen were elected members of the Society:—C. S. Sherrington, M.B.; A. W. Hughes, M.B., C.M.; T. W. P. Lawrence, M.B.

The following gentleman was nominated for election at the next meeting:—Edward Fawcett, M.B., C.M., Demonstrator of Anatomy at the Yorkshire College. Proposed by T. Wardrop Griffith, D. J. Cunningham, and Matthew J. Oliver.

Professor THANE gave an account of two *Abnormal Muscles of the Leg*:—

In the one specimen, which was exhibited, the abnormality consisted in the presence of a large *peroneo-calcaneus internus* (see figure 1). The fleshy mass arising from the lower two-thirds of the posterior surface of the fibula was divided longitudinally into two parts of nearly equal size; the inner of these had the normal arrangement of the flexor longus hallucis; the outer ended behind the ankle-joint in a tendon which passed beneath the internal annular ligament with the flexor longus hallucis, and was inserted into the fore part of the inner surface of the os calcis, just below the sustentaculum tali, and imme-

FIG. 1

diately external to the groove of the flexor longus hallucis. Examples of the peroneo-calcaneus internus, generally of small size, have been recorded by Meckel,[1] Macalister[2] (by whom the muscle was thus named), Davies-Colley, Taylor and Dalton,[3] Curnow,[4] and Knott,[5] while H. Hartmann[6] has described a specimen agreeing almost precisely with the one exhibited. Hinterstoisser[7] has seen a similar muscle arising from both the tibia and fibula, and named it *tibio-peroneo-calcaneus internus.* Meckel regarded the muscle as the homologue of the pronator quadratus of the upper limb, and Macalister compared it to the ulno-carpal slip sometimes detached from the pronator quadratus; while Testut[8] and Hinterstoisser look upon it as a reduced flexor accessorius longus. Turner[9] has described several cases of accessory muscles in the region of the inner ankle.

In the second case (fig. 2) the flexor accessorius of the foot was wanting. In the lower third of the leg there was a supernumerary muscular belly (* in figure) arising from the fascia over the flexor longus hallucis, and having the appearance of a flexor accessorius longus; this belly passed beneath the annular ligament with the flexor longus hallucis, and then ended in a tendon which crossed obliquely over the long plantar ligament to be inserted into the sesamoid bone in the tendon of the peroneus longus: it had no connection with the flexors of the toes. That this muscle is, however, a modified flexor accessorius longus, would seem to be shown by the condition met with by Chudzinski in the dissection of an Annamite.[10] Here there was no accessorius in the left foot, but there was a muscle arising from the tibia and fibula, and inserted into the sesamoid bone in the peroneus longus tendon as in the case now reported; while in the right limb the flexor accessorius was a fusiform muscle arising from the intermuscular fascia of the leg and ending in a tendon which bifurcated, the smaller part joining the tendon of the flexor longus digito-

FIG. 2.

[1] *Handb. d. menschl. Anat.*, 1816, vol. ii., p. 587.
[2] *Further Notes on Muscular Anomalies in Human Anatomy*, Dublin, 1868, p. 14.
[3] *Guy's Hospital Reports*, 3rd series, vol. xviii., 1873, p. 395.
[4] *Journal of Anatomy and Physiology*, vol. vii., 1873, p. 307.
[5] *Abnormalities in Human Myology*, Dublin, 1881, p. 23.
[6] *Bull. de la Soc. Anat. de Paris*, 1888, p. 1044.
[7] *Wiener Jahrbücher*, 1887, p. 410.
[8] *Les Anomalies Musculaires chez l'Homme*, Paris, 1884, p. 699.
[9] *Trans. Roy. Soc. Edin.*, vol. xxiv., p. 185, 1865.
[10] *Revue d'Anthropologie*, 1882, p. 623.

rum, and the larger passing to the ligaments of the second row of tarsal bones, thus forming a transition between the mode of termination of the common long accessory muscle and the more anomalous form running to the peroneus longus. In another instance Professor Thane had seen a small fibrous slip springing from the os calcis at the inner border of the long plantar ligament, crossing the outer head of the normal accessorius muscle, and inserted into the peroneal sesamoid, thus taking the course of the tendon of the anomalous muscle.

Mr T. W. P. Lawrence exhibited *Two Hearts with Abnormal Valves* (figures of which accompany this note). In one the pulmonary valve presented only two semilunar flaps, and in the other a similar abnormality was present in the aortic valve.

In the two specimens the semilunar flaps are sufficiently free from disease to permit of the exclusion of a pathological blending of adjacent fully-developed flaps as the cause of the anomaly. In the case of the pulmonary valve the segments are wholly free from disease; in that of the aortic valve the line of attachment to the wall of the vessel presents a slight thickening, a small atheromatous nodule is seated near each point of junction of the flaps, and from these masses induration has extended partially through the segments. In both specimens the heart is in other respects normally developed.

The segments of the abnormal pulmonary valve (fig. 1) are equal in

Fig. 1.—Pulmonary valve.

size, their free margins are even and present no notch or other irregularity. Their convex surface is not marked by any vertical groove, nor is there any central line of thickening, either in the substance of the flaps or upon the opposite arterial wall, such as is seen in examples of fusion of adjacent segments. Excepting their increase in size and extent of attachment, they present the characters of normal valve segments. Of the points of junction of the two segments the posterior, or that lying towards the aortic orifice, has the normal situation on the wall of the artery; that is to say, it is opposite the junction of the anterior with the left posterior aortic flaps. The other point of junction of the pulmonary segments has a

diametrically opposite position on the wall of the artery, and corresponds, therefore, to the mid-point of a sinus of Valsalva in a normally formed valve. The two segments of the aortic valve (fig. 2) are, as before mentioned, slightly deformed by atheroma and induration ; but the morbid changes are not such as will account for the abnormality. The two flaps are distinct, each has its normal semilunar form, and in neither of them is there any evidence of the fusion of two segments. There is an inequality in the size of the segments, the anterior or right being rather larger than the posterior or left, the latter corresponding with, although somewhat larger than, the left

Fig. 2.—Aortic valve.

posterior flap of a normal valve, and the left coronary artery springs from the middle of the corresponding sinus of Valsalva. The anterior point of junction of the two segments lies in its normal position opposite the junction of the posterior with the right anterior flap of the pulmonary valve. The right coronary artery arises from the larger sinus, and from its anterior third ; and in front of the situation of the junction of the anterior and right posterior segments when these are differentiated—a spot which may be localised without regard to the valve segments, since it is situated immediately superior to the pars membranacea of the septum ventriculorum. In the specimen the pars membranacea is within the larger pouch forming part of the outer or arterial wall, and its position in the figure is just below the end of the line pointing to the right aortic flap.

The explanation of these valvular anomalies is to be sought for in that period of embryonic development in which the aortic bulb is transformed into aorta and pulmonary artery. At the commencement of this process the undivided bulbus arteriosus develops, in connection with its inner or endothelial tube, four linear and vertical thickenings, which protrude as semi-cylinders into the lumen. Two of these thickenings on opposite sides of the tube are larger than the

remaining two. Their most prominent parts subsequently touch and fuse, and through their median planes and line of contact the division of the bulb takes place, producing two tubes, each of which contains one entire endothelial cushion and two half cushions. From these cushions the semilunar flaps are developed.

Of the two specimens the abnormality of the pulmonary valve is to be explained by assuming the suppression of the left anterior cushion, the remaining two half cushions developing into two equal flaps. The inequality in the size, and the special relations of the aortic segments in the second specimen prevent the explanation of the defect by an analogous suppression of the right posterior aortic cushion; and the condition of this valve is best accounted for by supposing that the anterior and right posterior aortic cushions have developed into a single flap.

Dr H. D. Rolleston showed a specimen in which there was a rudimentary valve segment between the right and posterior pulmonary valves. This additional fourth segment was rather below the level of the other three valves. Both it and the other valves were fenestrated.

The President then read a paper on the *Relations of the Dentary Arcades in the Crania of Australian Aborigines*, which will be found at vol. xxv. p. 461, of the *Journal of Anatomy and Physiology*.

Professor Thane, Mr Bland Sutton, and Dr W. Hill spoke upon the subject.

The Secretary, for Professor Cleland, then read the following paper:—

On Burial in Sand for Preparation of Bones.

"Some years ago, when looking at a skeleton of a seal which was in preparation at Professor M'Intosh's Marine Laboratory at St Andrews, I happened to remark on the presence of some oil in one of the bones, when the attendant replied—'That will give me little trouble; I shall put it in the sand for a while.' I then remembered what every one must have noticed—namely, how free from oil bones by the sea-shore are; and it occurred to me for the first time, how absurd it was to suppose that a cleansing which was carried to the heart of the bone could be effected by sand lice. I concluded that it was most probable that every time that the tide ebbed, the water in the sand exercised a dragging force as it was carried down, and that the interior of a bone could not be exempted from this, but would be exposed to a prolonged and regularly applied slow influence tending to draw materials from its interior. It was impossible to be certain without experiment that the sea-water did not in some other way favour the removal of oil, and, even if my supposition were true, it had yet to be taken into consideration that sea-water was heavier than fresh. But when I came back to Glasgow I had a cartload of sand deposited in a paved

court, and proceeded to test the influence of burial in sand with exposure to the rain. The bones of a fine zebra and a large kangaroo, with the larger masses of muscle roughly removed, were buried in summer in the sand heap, and emerged in the following spring beautifully clean and as free from oil as could be desired. They caused no bad smell in the court, and when they were taken out required only to have the sand washed off them and to be dried to be ready for articulating. Afterwards I buried, with the skin on, a young polar bear, which came at an inconvenient time and in an offensive condition. But a winter was not sufficient to make it ready, obviously because the skin prevented the freedom of currents, but I put in a number of human bones which had got so frightfully greasy lying for years in drawers that they were quite unfit for exhibition, and they emerged after a time thoroughly clean, and I was so pleased with the result that I treated in the same way a whole skeleton which had been articulated several years before for the purpose of showing old-age peculiarities, and had got so greasy that it had been put away, and had narrowly escaped being sent to the churchyard. The result in this instance was very remarkable. The light porous bones of old age are exhibited without a trace of oil left in them. The sandheap has never been in the least offensive. The products of putrefaction appear to soak away gradually to the drains. I notice that when there are copious remains buried in it, it becomes the resort of innumerable springtails, but these are no more capable of cleaning bones to the heart than are the sand lice by the sea-shore.

"The importance of sand burial as a means of preparing bones depends not merely on its being one of many methods by which recent specimens may be properly prepared, but as being the most effective way of purifying old specimens from oil, and still more as being greatly superior to maceration for specimens which have been obtained from dissecting-rooms in which strong preservations are used. Remains from the rooms in this school are accordingly difficult to macerate, but they come from the sand heap white in colour, and with the spicules of the cancellated tissue thoroughly clean."

Dr Herbert Spencer then read a paper on *Ossification in the Head of the Humerus at Birth*, which will be found at vol. xxv. p. 552, of the *Journal of Anatomy and Physiology*.

Dr Wardrop Griffith then read a paper on a case of *Congenital Malformation of the Heart with Transposition of the Viscera*, which will be printed in a subsequent number of the *Journal of Anatomy and Physiology*.

Professor Thane, Mr Bland Sutton, Dr Herbert Spencer, and Dr Rolleston spoke upon the subject, and Dr Wardrop Griffith replied.

Mr C. B. Lockwood and Dr H. D. Rolleston then read a paper on the *Situation of the Vermiform Appendix*, and showed illustrative

specimens. The following is an abstract of their results, which later will be published in greater detail:—

Notes of the Position and Condition of the Vermiform Appendix in 100 *consecutive Cases in which there was no manifest Morbid Condition of the Abdominal Cavity.*

There were 61 male and 39 female subjects. The ages varied from 13 weeks to 70 years.

Normal Conditions.—When pervious or perfectly free, with a mesentery allowing it to be moved in all directions, the appendix was considered to be normal. (1) In many cases it lay under the inferior layer of the mesentery, and directed towards the spleen. (2) In many other cases it lay on or over the brim of the pelvis. These were the two most frequent positions, and it seems a matter of chance which is found, as it can easily be shifted from one to the other. It may also lie (3) over the cæcum and ascending colon, (4) to the right of the cæcum and ascending colon, or (5) under the cæcum.

In the 39 female cases the normal condition was noted 26 times giving a percentage of 66·6.

In the 61 male cases the condition occurred 32 times, or 52·6 per cent.

In nine other cases the appendix, though free, was found to be obliterated—five times in males, four times in females.

In six of the cases for its whole extent, in the other three cases partially only.

Abnormal positions of the appendix may be considered as being caused (1) by deficiency of its mesentery, which results in the vermiform appendix being fixed to the peritoneum; (2) by the existence of pouches of peritoneum such as the ileo-cæcal or sub-cæcal fossæ, which may contain the free appendix; (3) by a combination of these two factors resulting in the vermiform appendix being curled up in and adherent to the wall of a peritoneal pouch.

The abnormal positions may be classified as cases in which the appendix is—

(1) Adherent to the peritoneum in the region of the sub-cæcal fossa, that fossa not being present. Noted 4 times—3 in males, 1 in females.

(2) Adherent to the under surface of the cæcum. Noted 4 times—2 in males, 2 in females.

(3) Coiled up in sub-cæcal pouch. Noted 10 times—8 in males, 2 in females.

(4) Fixed to peritoneum along the right border of cæcum and colon, the tip often being free. Noted 4 times—3 in males, 1 in females.

(5) Fixed to peritoneum in region of the ileo-cæcal fossa, that pouch not being developed. Noted 4 times—all in male subjects.

(6) Coiled up in ileo-cæcal pouch. Noted 5 times—2 in females, 3 in males.

(7) Hidden completely in pouch the mouth of which has become closed. Noted 2 times—both in males.

SUMMARY.

Vermiform appendix, free, movable, pervious,	58
" obliterated,	6
" partially obliterated,	3
Abnormal positions, adhesions, hernias, &c.—	
(1) In sub-cæcal region adherent to peritoneum,	4
(2) Adherent to under surface of cæcum,	4
(3) In sub-cæcal pouch,	10
(4) Fixed to right of cæcum,	4
(5) In ileo-cæcal region adherent to peritoneum,	4
(6) Coiled up in ileo-cæcal pouch,	5
(7) Hidden completely,	2
	100

INDEX TO PROCEEDINGS OF ANATOMICAL SOCIETY.

PROCEEDINGS OF THE

SCOTTISH MICROSCOPICAL SOCIETY.

FIRST SESSION, 1889-90.

LIST OF OFFICE-BEARERS.

President—Professor Sir Wm. Turner, F.R.S., LL.D., D.C.L.
Vice-Presidents—Professor D. J. Hamilton, F.R.S.E.; Adolf Schulze, F.R.S.E.
Secretaries—Alexander Edington, M.B.; George Brook, F.R.S.E.
Treasurer—Professor John M'Fadyean, M.B., B.Sc.
Curator—G. S. Woodhead, M.D.
Council—Professor Annandale, F.R.C.S.E.; Professor I. B. Balfour, F.R.S.; Professor W. S. Greenfield, M.D.; J. B. Haycraft, M.D., D.Sc.; Professor James Hunter, F.R.S.E.; Robert Kidston, F.R.S.E.; Professor W. C. M'Intosh, M.D., F.R.S.; R. Peel Ritchie, M.D., *P*.R.C.P.E.; Professor Wm. Rutherford, M.D., F.R.S.

LIST OF PAPERS READ.

NOVEMBER 1, 1889.

Inaugural Address on the "Cell Theory, Past and Present," by the President, Sir WILLIAM TURNER. This has been published in the *Journal of Anatomy and Physiology*, vol. xxiv. p. 252.

NOVEMBER 15, 1889.

"On the Histology of the Zoantharia," by GEORGE BROOK, F.R.S.E.

"Demonstration of the Histology of the Whale's Stomach," by G. S. WOODHEAD, M.D., and ROBERT GRAY.

"On the use of Blood Serum as a medium for Injection Masses, by G. C. Purvis, M.D., B.Sc.

"A new Inoculating Syringe for Bacteriological Purposes," by Alex. Edington, M.B.

December 20, 1889.

"On some Points in the Structure of the Retina of the Rabbit and Mouse," by G. Carrington Purvis, M.D., B.Sc.

"A Demonstration of some Epithelial-like Cells in the Sclerotic of the Mouse," by G. Carrington Purvis, M.D., B.Sc.

"On a Rudimentary Glandular Structure from the Upper Jaw of *Balœna mysticetus*, which may represent the Parotid," by Robert Gray.

"Demonstration of Tubercle Bacilli from the Domesticated Animals," by Professor J. M'Fadyean, M.B.

January 17, 1890.

"On the Fate of the Notochord and Development of the Intervertebral Disc in the Sheep," and "On the Structure of the Adult Disc," by E. W. Carlier, M.B., B.Sc. This paper has been published in the *Journal of Anatomy and Physiology*, vol. xxiv. p. 573.

"Notes on the Growth of a Fungus," by Professor Greenfield, M.D.

"Demonstration on Motor and Peculiar Sensory Nerve-Endings in the Skate," by G. Carrington Purvis, M.D., B.Sc.

"Exhibition of a New Steam Steriliser, and of Improvements in the Rocking Microtome," by Alex. Frazer, M.A.

February 21, 1890.

Exhibition of a Manufacturer's and Warehouseman's Microscope, by Adolf Schulze, F.R.S.E.

"On the Structure and Contraction of Striped Muscular Fibre," by Professor Rutherford, M.D., F.R.S.

"On the Microscopic Structure of some Plant Hybrids," by J. M. Macfarlane, D.Sc., F.R.S.E.

March 21, 1890.

"The Histology of the Carapace of the Chelonia, with an Account and Demonstration of the Termination of Nerves in the Nuclei of the Epithelial Tissue of the Scutes," by J. B. Haycraft, M.D., D.Sc.

"Demonstration of the Fructification of some Carboniferous Ferns," by Robert Kidston, F.R.S.E.

MAY 16, 1890.

"On some Points in the Histology of the Tongue of the Canary," by W. H. BARRETT, M.B.

"Lantern Demonstration on Dental Pathology," by G. W. WATSON, L.D.S.

JUNE 20, 1890.

"On the Development of the Carapace in the Chelonia," by J. B. HAYCRAFT, M.D., D.Sc.

"On the Microscopic Structure of the Electric Organ of *Raia batis*," by G. CARRINGTON PURVIS, M.D., B.Sc.

"A Demonstration of some New and Recent Staining Methods," by E. W. CARLIER, M.B., B.Sc.

SECOND SESSION, 1890-91.

LIST OF OFFICE-BEARERS.

President—Professor William Rutherford, M.D., F.R.S.
Vice-Presidents—Adolf Schulze, F.R.S.E.; Professor Bayley Balfour, M.D., F.R.S.
Secretaries—George Brook, F.R.S.E.; Alexander Edington, M.B.
Treasurer—Professor J. M'Fadyean, M.B., B.Sc.
Curator—Professor W. S. Greenfield, M.D., F.R.C.P.
Councillors—J. Berry Haycraft, MD., D.Sc.; Professor James Hunter, F.R.C.S.E.; Robert Kidston, F.R.S.E.; R. Peel Ritchie, M.D., F.R.C.P.; Joseph Coats, M.D.; J. M. Macfarlane, D.Sc.; James More, junr., Assoc. Memb. Inst. C.E.; Rev. A. B. Morris; J. Symington, M.D., F.R.C.S.E.; Professor Sir W. Turner, F.R.S.

NOVEMBER 7, 1890.

The Chair was taken by the retiring President, Sir WILLIAM TURNER. The Treasurer read an Abstract of the Society's Accounts for the previous Session, which showed a balance of £94, 19s. in favour of the Society. At the conclusion of private business, the retiring President vacated the chair, which was taken by his successor, Professor WILLIAM RUTHERFORD, who delivered the following Inaugural Address:—

THE TERCENTENARY OF THE COMPOUND MICROSCOPE.

GENTLEMEN,—I have to thank you for the honour of being elected President of this Society for the session which we open this evening.

This year happens to be the tercentenary of the invention of the compound microscope, and it seems appropriate that I should on this occasion briefly review the history of the microscope, its present position, and the difficulties that impede its further progress.

The microscope far surpasses all other instruments in the help it has rendered to biological science. Without its aid the cellular structure of plants and animals would still have been unknown; the minute structure of their organs would still have been matter for conjecture; the wonderful changes that characterise the development of complex organisms would still have been a mystery; and the theory of evolution which has to a large extent sprung from the law of cellular development might not yet have been advanced. Without the microscope, the nature of many diseased processes would still have been unknown, and the physician still baffled in his search for rational methods of treatment; without the microscope, some of the most dangerous causes of disease would still have remained undetected, and the rational principles of antiseptic surgery would not yet have been enunciated; and, without its help in medico-legal inquiry, the ends of justice would on several occasions have been defeated. Through no avenue of sensation, so much as through the eye, has our knowledge of nature been gained, and marvellous though the efforts of nature have been in evolving our wonderful organ of sight, it is to the glory of science that she has brought the telescope and the microscope to its aid—the one to penetrate the veil of distance and reveal the nature of the stellar universe and the gigantic scope of creation; the other to break the seal covering objects of small dimension, and to reveal to us many of their wonderful properties, and some of the great laws that govern the operations of living nature. With the range of human vision thus extended the mind has been enabled in some measure to realise the wonders of nature revealed in her greatest and in her smallest objects, and to perceive some of the great laws that have dominion over them.

No one knows exactly when the simple microscope was invented. Burning glasses were so common in Greece that they were sold as curiosities in the toy shops. Such glasses must have been convex, and could therefore serve as magnifying as well as burning glasses. It has been argued with good reason that the engraving of ancient gems could not have been executed without the help of a magnifying glass; while on the other hand it has been contended, but with questionable logic, that if magnifying glasses had been known to the ancients they could scarcely have failed to use them as spectacles, and to have alluded in their medical writings to the help which magnifying glasses can give to sight. But it appears that no such allusion is ever made by any Greek or Latin author, or indeed by modern authors, until the close of the thirteenth century, when

spectacles were invented by Armati of Florence about the year 1285. It seems to me quite possible that a single lens might have been used by an engraver of gems long before the advantage of placing such a lens in front of each eye became known.

The compound microscope dates from the year 1590, as nearly as can be ascertained. Hans Janssen, or his son Zacharie, spectacle makers at Middelburg, in Holland, discovered that the magnified image of an object produced by a convex lens can be still further magnified by looking at it with a similar lens. They discovered the principle of the *indirect amplification of an object*, and thus invented the double microscope. Eighteen years afterwards (1608) the telescope was also invented in Holland. Neither of these instruments was *invented* in Italy by Galileo, although he *constructed* both of them. Recently an Italian physicist, Professor Govi,[1] has claimed the invention of the double microscope for Galileo, but there is sufficient evidence that he arranged lenses to form a double microscope after he had obtained a telescope from Holland; while as a matter of fact the double microscope was invented in Holland eighteen years *before* the telescope. There need therefore be no doubt that the credit of the invention of both instruments belongs to the Dutch.

Some seventy years after Janssen's invention, Robert Hooke, secretary of the Royal Society of London, devoted much attention to the microscope, and made several suggestions worthy of note. His work, entitled *Micrographia*, published in 1665, contains many curious observations on plants and animals and on other subjects, and is illustrated by elaborate drawings. He principally used a double microscope with one lens for the object-glass and another for the eye-glass; but it is to be observed that his eye-glass was much wider in proportion to the object-glass than in the Janssen microscope, for a reason that must be obvious. He tells us that when he desired to see a greater extent of the surface of an object, he *introduced a third lens* in the position of what is now termed the field glass,[2] but whenever he wished to see the object very clearly, to examine its minute details, he took out the third glass, because, as he said, "the fewer the refractions, the brighter and clearer the object." The Dutch optician, Huygens, the celebrated author of the undulatory theory of light, had previously used such a glass in the eyepiece of the telescope, and therefore his name is commonly associated with an eyepiece so constructed.

Hooke was so persuaded that the only way to see clearly with the microscope is to diminish the number of refractions, that he invented one in which the space between the object-glass and eye-glass *was filled with water*, so that the refraction at the upper surface of the object-glass and lower surface of the eye-glass might be greatly lessened. With water in place of air, the image of an object viewed through such a microscope was more brightly illuminated because of diminished loss of light by reflection at the inner glass surfaces, but

[1] See abstract and criticism in *Jour. Roy. Mic. Soc.*, 1889, p. 574.
[2] R. Hooke, *Micrographia*, London, 1665.

as its employment was inconvenient, it was abandoned. By that invention Hooke showed his perception of a principle that afterwards led to the construction of immersion lenses. He complained that the apertures of object-glasses were so small that "very few rays were admitted, and that many of them were so false that the object appeared indistinct." He believed "that these inconveniences are inseparable from all spherical glasses, and to diminish them he recommended a bright illumination of the object by a convex glass, such as a globe of water, or a *deep plano-convex lens whose convex surface is turned to the window, and its plane surface to the object.* But he was obliged to admit that a solid bead of clear Venice glass fixed in a small hole in a metal plate would magnify more highly, and show some objects more distinctly than any of the great microscopes.

The celebrated Dutch observer Leeuwenhoeck appears to have arrived at a similar conclusion, for most of his microscopical observations were made with a simple globule of glass, mounted between two metal plates, pierced with a minute aperture to allow rays to pass only through the central portion of the lens.

Previous to the introduction of achromatism the compound microscope underwent some improvements in the hands of Campani, Divini, and others; but I must pass them over to briefly notice the additions made by a London optician, Benjamin Martin. His work on optics,[1] published in 1740, is a lucid exposition of the subject, and admirably illustrated. His construction of the mechanical parts of the microscope had the great excellence ever since maintained by English opticians. He added a rack and pinion for moving the body of the instrument; a nosepiece for carrying different lenses; a double mirror to illuminate transparent objects; and a stage with rectangular movements accomplished by fine screws with graduated heads, so that the extent of motion in any direction could be accurately determined as in the movable stages now made.

For more than two centuries the microscope awaited the correction of the great faults of spherical and chromatic aberration inherent in its lenses. The great step that led the way to its modern development was the invention of achromatic lenses by the English optician, John Dollond. His celebrated "Account of some Experiments concerning the different Refrangibility of Light" was published in the *Philosophical Transactions* for 1759. The account is remarkably brief and concise. One requires to read it in order to realise that in discovering the different optical properties of flint and crown glass, which enabled him to construct an achromatic lens, he had to prove Sir Isaac Newton to be in error, and all the opticians who adopted his teaching and believed that *the refractive and dispersive powers of an optical medium are always equal.* Dollond proved that to be an error by comparing the refractive and dispersive powers of glass and water. His experiment was essentially this: he took a triangular glass prism and a wedge-shaped trough made of plate glass and filled with water. He arranged them with bases reversed, so that the one

[1] *A New and Compendious System of Optics*, by B. Martin, London, 1740.

might counteract the other. His glass prism had an angle of 60°, and he experimentally ascertained the angle required for the water prism to compensate the refraction of a beam of light by the glass. On looking at a white object through both prisms thus arranged, he observed that although the object did not appear shifted in position it seemed to be coloured. Therefore, although the water had compensated the refraction which the mean rays of the luminous beam had suffered in the glass prism, *it had not recomposed white light*, and he perceived this to be due to the dispersive power of glass being nearly twice as great as that of water. He then increased the angle of his water prism until it compensated the dispersion produced by the glass, and recomposed white light; but he found that although the object now appeared colourless, it seemed shifted in position, because the ray emerging from the prisms had been refracted from the plane of the incident ray.

By these simple experiments Dollond proved that the refractive and dispersive powers of an optical medium may be unequal, and that it is possible to compensate the chromatic dispersion of light and still obtain a final bending of the beam. Dollond made these experiments in 1757, two years before he published his paper, and he immediately proceeded to construct new object-glasses for the telescope. He at first made them of "two spherical glasses with water between them," and he found them "free from chromatic errors." But the errors due to spherical aberration were still so great that he gave up all hope of success with lenses of such construction. He was led to "*suspect that different sorts of glass might possibly be found to show differences in the ratio of their refractive and dispersive powers.*" So that he says (p. 739) "the next business to be undertaken was to grind wedges of different kinds of glass and apply them together so that the refractions might be made in contrary directions, in order to discover whether the refraction and the divergence or dispersion of the colours would vanish together." He then says (p. 740), "I discovered a difference far beyond my hopes, in the refractive qualities of different kinds of glass, with respect to their divergency of colours. The yellow or straw-coloured foreign sort, commonly called Venice glass, and the English crown glass, are very near alike in that respect, though in general the crown glass seems to diverge the light rather the least of the two. The common plate glass made in England diverges more, and the white crystal or flint English glass, as it is called, most of all. It was not now my business to examine into the particular qualities of every kind of glass that I could come at, much less to amuse myself with conjectures about the cause, but to fix upon such two sorts as their difference was the greatest, which I soon found to be the crown glass."

Dollond's communication is remarkable for lucidity and brevity; probably few other papers limited to nine octavo pages have chronicled an advance so important in practical science. But Dollond's originality has been questioned. Thomas Young, in his *Lectures on Natural Philosophy*, published in 1807, states[1] "that

[1] P. 380, Kelland's edition, published 1845.

Dollond was led to make experiments on the refraction of different kinds of glass in consequence of a discussion with Euler, Klingenstierna, and some other mathematicians," but although Dollond probably received suggestions from others, to himself alone appears to belong the credit of having made the first achromatic lens. Euler, in his *Letters to a German Princess*, wrote on the 19th of August 1760—a year after Dollond's paper was published—that, although chromatic aberration could be remedied by combining lenses of different substances, "neither theory nor practice have hitherto been carried to the degree of perfection necessary to the execution of a structure which should remedy the defect."

From the extract I have read from Dollond's paper, it appears that he aimed at the correction of both spherical and chromatic aberration in lenses by correcting the positive aberration of a biconvex of crown glass by the negative aberration of a plano-concave of flint glass—and he succeeded in doing both—to a large extent. He relied on the degree of concavity in the flint lens to remove the positive spherical error of the crown lens, and on the nature of the material, as well as on the curvature, to remove the chromatic error. As a matter of fact, however, the chromatic fault, although greatly diminished, was never completely removed, nor was the spherical fault ever completely abolished; nor could they be by the simple combination of a single convex and a concave lens of crown and flint glass.

Dollond's achromatic lenses were made for the telescope in 1758, but, strange to say, their application to the microscope seems to have been very tardy, apparently because Dollond devoted his attention specially to the telescope. Achromatic objectives of crown and flint glass on Dollond's principle were at length made for the microscope by Frauenhofer of Munich in 1811, and Amici of Modena in 1815, but apparently with no great success.

The achromatic microscope as now commonly employed, really dates from 1823, when Chevalier of Paris, instructed by Selligue, made high power objectives on the principle of superimposing several achromatic doublets, instead of attempting to obtain a high power from a single lens. This method was well known in the simple microscope, and it is remarkable that its application to the compound instrument was not sooner thought of. Another novel feature was the cementing together of the flint and crown lenses in each doublet, whereby the loss of light by reflection within the doublet was greatly diminished. At first the convex surface of each lens was turned to the object, with the consequent production of great spherical aberration that rendered the lens of little value, unless the pencil of light was made very narrow by a diaphragm. Chevalier afterwards shortened the focus of each doublet, turned their plane surfaces towards the object, and thus greatly reduced the spherical aberration.

Within a year after the appearance of Selligue's lenses, the London optician, Tully (1824), made triple achromatic object-glasses, which defined with "great sharpness;" but the impulse which enabled English opticians to rise to their prominent place as makers

of achromatic lenses appears to have been given by Joseph Jackson Lister in a paper published in 1830,[1] in which he showed that Selligue's method of superposition of achromatic doublets in the objective was capable of yielding results not hitherto attained, because the key to them had not previously been found. Lister laid due stress on the principle that an objective must have a large angle of aperture to give a brilliant and distinct image. He showed that the marginal rays of a luminous pencil are those which specially serve to resolve fine closely adjacent lines such as those on the scales of Lepidoptera, as may be proved by the fact that some of the most difficult of these lines are best seen when only the marginal rays are employed and the central rays stopped out. He stated that the "great requisite for the object-glass of a compound microscope is a large focal pencil free from aberration; that the field should be flat and well defined throughout, and that the light admitted should as far as possible be only that necessary for the formation of the picture, and that it should not be intercepted or diffused over the field by too many reflections." He said that the prominent obstacle to obtaining a sufficient pencil of light for high powers by one object-glass of large aperture and deep curves is, that the correction for spherical aberration by the concave lens is proportionally greater for the marginal than for the central rays, so that there is over-correction of the marginal rays and the image consequently rendered indistinct, and at the same time coloured. It, therefore, becomes necessary to cut off the marginal rays, and so diminish the aperture of the lens. Lister was the first to show that by superposition of achromatic doublets the effective aperture of the series of lenses can be widened by a precise adjustment of the distance between them, and by accurately centering them around the optic axis. In combining several lenses together he says "it is often convenient to transmit an under-corrected pencil from the front glass, and to counteract its error by over-correction in the middle one" (p. 199). These apparently simple indications were what he termed the "key" to the improvement of achromatic objectives.

Lister's suggestions were promptly acted on by London opticians, more especially by Smith and Beck, Andrew Ross, and Hugh Powell, whose ingenuity and skill rapidly raised English microscopes to the first rank for optical as well as mechanical excellence. No better testimony could be given to Lister's acuteness in 1830, than that furnished by Professor Abbe[2] in 1879 in his paper on the correction of spherical and chromatic aberration, where he shows the great importance of the relative distance between the lenses of an objective, and the excellent results attainable when an under-corrected pencil of light is transmitted to over-corrrected lenses placed at a suitable distance above the under-corrected front lens, the compensating power

[1] "On some Properties in Achromatic Object Glasses applicable to the Improvement of the Microscope," by J. J. Lister, *Phil. Trans.*, London, 1830, part i., p. 187.

[2] Abbe "On New Methods for Improving Spherical Correction applied to the construction of Wide-Angled Object-Glasses," *Jour. Roy. Mic. Soc.*, 1879, p. 812.

of the upper lens depending to a considerable extent on the relative distance beeween them and the lower lens. The ordinary high power objectives devised by Abbe consist of an uncorrected lens placed in front, and three over-corrected doublets placed behind it, in which the spherical and chromatic errors of the front lens are removed.

Few points in microscopical optics have been more discussed than the *aperture of the object-glass.* Let me remind you that the angle of aperture of an objective is the angle formed between the most external rays that can penetrate *the entire system of lenses* from a luminous point in the focus. But in many object-glasses the lenses cannot be used to the full extent of their aperture, owing to the serious increase of spherical error in the marginal portion of the lens. Therefore it is frequently necessary to intercept the passage of rays through the marginal portion, and thus to curtail the aperture. Indeed, the angle of aperture of a lens is in practice reduced to the angle between the most peripheral rays that are capable of forming a correct image. Therefore a large angle of aperture is only possible when the spherical and chromatic faults of a system of lenses have been so well corrected that rays transmitted by the outer zones of the lens can form a distinct image.

The power of an object-glass in resolving fine adjacent lines increases with its angle of aperture as Lister pointed out. Therefore opticians have been constantly striving to produce lenses of large aperture. The lens with the highest angle yet produced is Abbe's apochromatic oil immersion of 134°. Abbe has shown that it is vain to attempt to increase the angle appreciably beyond this, because the focus of the lens is so short, and the incidence of the peripheral rays so oblique, that with a higher angle the lens would be practically useless. Objectives of large aperture are valuable for the study of bacteria, muscle fibrils, and all objects with fine markings, but they are not so serviceable as those of small angle for the ordinary study of the structure of tissues and organs, because the *penetrating power*, that is, the power of seeing objects a little above, and also below, the exact focus, diminishes as the angle of aperture is increased. The method of indicating the aperture of an object-glass by stating its angle has been found inconvenient, because the angles have a relative value only when lenses are used in the same medium. be it air, water, or oil. An angle of 100° for a water-immersion lens indicates a greater resolving power than a similar angle in a dry lens, Abbe has therefore proposed to supersede the angular designation of aperture by the more convenient method of indicating the aperture numerically. The *numerical aperture* is obtained by multiplying the sine of half the angle of aperture by the refractive index of the medium through which the light reaches the lens, be it air, water, or oil. The numerical aperture is an index of the resolving power of an objective, irrespective of the medium in which it is immersed. Thus a lens whose power of resolving fine lines is indicated by the numerical aperture 1·0, would have, *in air*, an angle of 180°; *in water*, an angle of 97° 31″; and in cedar oil, an angle of 82° 17″. That

illustration is sufficient to show what confusion may be avoided by adopting the numerical aperture as an index of resolving power. The numerical aperture of objectives may vary from as low as 0·05 to the comparatively high figure of 1·4, the aperture of the highest apochromatic oil-immersion lens made by Zeiss.

The remarkable increase of the resolving power of lenses, which has taken place in recent years, would have been impossible but for the adoption of the immersion principle. We are indebted to Amici of Modena for the invention of immersion lenses in 1840, or shortly after. To him belongs the credit of having been the first to aim at the construction of *homogeneous* immersion lenses. Knowing that certain oils have a refractive index similar to that of glass, he constructed lenses to be immersed in them, so that the refraction and reflection at the upper surface of cover glass and lower surface of objective might practically be abolished. It was a similar idea that led Robert Hooke nearly two centuries before to fill the tube of the microscope with water. The Italian microscopists, however, found the oil attack the surface of the lens, so that Amici was obliged to abandon it and make lenses for immersion in water. In making lenses for oil immersion fifty years ago, Amici was before his time, because powerful objectives with a sufficiently large angle of aperture to take advantage of the homogeneous immersion principle had not then been constructed. Amici exhibited his water-immersion lenses in Paris, and similar objectives were made there, but they were soon surpassed by the immersion systems made in this country by Powell and Lealand. The adoption of the immersion principle for high power objectives has permitted of their construction with a larger aperture, so that their resolving power is increased; but for very high power lenses water has now given place to thickened cedar oil, having refractive index 1·512, which is so nearly that of crown glass (1·53), that when interposed between the cover glass and lens it virtually forms with them a homogeneous optical system, in which there is practically no reflection or refraction at upper surface of cover and lower surface of lens: consequently illumination and definition are improved, and resolving power increased, because the oil permits of the lens being constructed with a larger aperture than is possible with a water lens. The highest numerical aperture of the oil lenses made under Abbe's direction is 1·4, which is regarded by him as the highest useful aperture. He believes it impracticable to attempt any further increase of aperture, because of the difficulty of overcoming spherical aberration, which increases with the aperture.

The first oil-immersion lens in the recent period of the microscope was constructed by Zeiss from a formula calculated by Abbe,—at the suggestion of Mr J. W. Stephenson, treasurer of the Royal Microscopical Society. The celebrity so rapidly attained by the firm of Zeiss, as practical opticians, is mainly due to their association with a skilled mathematician and master of optics in the person of Professor Abbe. The association of the mathematical theorist with the practical optician is always desirable, and in these times no optician need hope to accomplish anything remarkable unless he is himself

deeply versed in mathematics, or instructed by a mathematician willing to turn his attention to optics. The University and the factory seldom join hands, but the results of such union achieved in the small town of Jena show how much the honour of a country, as a producer of philosophical instruments, may be promoted by such combination. All who use the microscope must ever remain indebted to Abbe for having solved some of the most embarrassing difficulties in practical optics that completely baffled all who preceded him. Until he devoted his mind to the subject, there was no such thing as a compound microscope in which spherical and chromatic aberration was completely corrected, consequently the image produced by the objective was so faulty that deep eyepiecing was ineffective, and owing to yellow and violet rays being brought to different foci, it was difficult to use the microscope in photography. The main difficulty arose from the peculiar difference in the dispersive powers of flint and crown glass. If a prism of flint and another of crown glass are made of such angles that the same beam of light transmitted through each prism gives rise to a spectrum of the same length in each case, and the two spectra are shown side by side, it is found that they are not identical. The junction of the green and blue is nearer the violet end in the crown glass spectrum, and nearer the red end in the flint spectrum. Therefore, since the several parts of the two spectra are not in complete correspondence, the chromatic dispersion of crown glass cannot be completely corrected by that of flint glass; there must always be a residue of non-achromatised light, which produces what is termed a secondary spectrum, and therefore gives rise to a slightly coloured image. Consequently, in the best ordinary achromatic objectives, the chromatic error has never been corrected for more than two colours of the spectrum—the red and yellow; while spherical aberration was not corrected for more than one part of the spectrum—viz., the yellow line D given by a sodium flame. It was undercorrected for the red and overcorrected for the blue rays. A residue of imperfectly corrected spherical aberration is more detrimental than uncorrected chromatic aberration, because it impairs the definition of the object, and renders the image incapable of being highly magnified with advantage.

It was felt impossible to remove these difficulties without the aid of glass differing in composition from that of the old crown and flint glass commonly employed. Abbe therefore sought the aid of Dr Schott, a chemist experienced in glass making, and numerous experiments were undertaken. As many as a thousand specimens of glass of different composition were prepared; a prism made from each, and its refractive and dispersive powers determined, with the result that as many as forty-four different sorts of optical glass were obtained, nineteen of them being entirely new. The old flint glass consists chiefly of silicates of potash and lead, while crown glass consists of silicates of potash and lime. Abbe and Schott have made new sorts of flint and crown glass, which have a dispersive power very nearly in the same ratio for all parts of the spectrum, so that the secondary spectrum of achromatic combinations can be almost completely eliminated. The

Rev. W. Harcourt had previously ascertained that glass containing salts of boracic acid has peculiar properties, an observation that has been turned to good account at the Jena glassworks. Different sorts of glass containing borates, and others containing phosphates have been obtained, and are now used with siliceous glass in the finest lenses. The new optical glass has from the first been generously supplied to all opticians, and a marked improvement in the microscopes produced in London and elsewhere has been the result of Abbe and Schott's experiments in glass-making.

With the help of the new glass Abbe has been able to devise the finest lenses that have yet been made. They consist of five lenses, in which the new crown and flint glass, and glass containing borates and phosphates are used. He has termed the new lenses *apochromatic*, because they are practically free from chromatic and spherical faults. They bring the red and violet and other rays of the spectrum to precisely the same focus, so that they are of the greatest value for photography. When the lens is so arranged that the object is most clearly seen on the plate of the camera, further adjustment is unnecessary, because the chemical rays are in the same focus as the most visible rays. Spherical aberration is corrected for two colours of the spectrum instead of one as in previous lenses, so that it is practically abolished even when the full aperture of the lens is used. By bringing practically all the rays of the spectrum into one focus, the image is better defined, and can bear deep eyepiecing. However, I think, I may safely say that the chief value of these lenses is in photography, where they certainly give us great help; but for ordinary microscopic observation the advantage they give over the old lenses is not so great as one might have anticipated. The apochromatic objectives are intended to be used with eyepieces of new construction, termed *compensating*, because they have been designed by Abbe to compensate the slight residual faults of the objective. They are a great improvement on the old oculars, and give a sharper image even when used with the old objectives. With reference to the eyepiece, we must not forget our indebtedness to Huygens for the double eyepiece he invented for the telescope, and which has now for so long a time been used in the compound microscope.

It is evident that within the last few years the compound microscope has made remarkable progress notwithstanding difficulties that for a long time appeared insurmountable. Within the brief period of some twelve years the principle of homogeneous immersion has been carried into practice; new kinds of optical glass have been compounded, and apochromatic objectives and compensating oculars invented. It is only just to say that we owe these valuable results mainly to the mathematical skill and deep insight of Abbe, but notwithstanding the rapid advances recently made, we are not permitted by him to anticipate any great future advance in the microscope's power of resolving fine details. Its power of so doing is not capable of indefinite extension; the nature of light itself prevents it. The very light that so readily reveals the objects around us will not allow us to see the interval between a pair of lines if it is less than

half the wave length of the light; indeed, with *central* illumination the interval must not be less than a wave length to be rendered visible. Therefore, the light of the *visible* part of the spectrum renders the microscope unable to resolve parallel lines of more than 118,000 to an inch; indeed, for a serviceable lens the lines must be not more than 95,000 to an inch. This limitation chiefly results from the phenomena of *diffraction*.

The *interference* and *diffraction* of light have so great an influence on the appearances presented by certain objects under the microscope that I would ask your attention to that subject for a little. You will find on the table an oxyhydrogen lantern, with its ordinary condenser inside, and an adjustable metal slit in its aperture. The lantern slit has been opened to the extent of two or three millimetres to get a thin beam of light, and if you place your eye in its path, and look through an adjustable slit held close to the eye with its long axis parallel with the lantern slit, and opened only to the extent of a millimetre or less, you will readily observe a central bright band, and on either side of it a fringe of fainter bands gradually disappearing at the sides. The bright central band is produced by the principal rays passing through the slits, while the fringes of alternate light and dark bands arises from diffraction of a portion of the light in passing through the narrow slit before the eye, and from the mutual interference of the diffracted rays (fig. 1). If you vary the

Fig. 1.—Principal (p) and diffraction bands (d) produced by the same slit with red (r), green (g), and violet light (v).—Ganot's *Physique*.

width of the slit before the eye you will find on making it *narrower* that the principal and the diffraction bands all *widen* out and become separated to a greater distance owing to a similar widening of the dark interference bands. If a circular aperture is substituted for the slit at the lantern, you find on looking through the ocular slit a central bright spot, and on each side of it a row of crescentic diffraction bands extending *laterally* from the slit in whatever position it is placed, proving convincingly that the diffraction phenomena in both cases are produced by the narrow slit close to the eye, and vary with its width. You will further observe that with ordinary light every diffraction band is a spectrum with the red always on the side farthest from the principal band.

If you successively place behind the lantern slit plates of red,

green, and blue glass, you find that all the light and dark bands are broadest with red, and narrowest with blue, and intermediate with green light. The difference arises from the waves of red being longer than those of green, and these in turn longer than those of blue light.[1]

The undulations of light, like those on the surface of a liquid, are transverse to the path they pursue. They radiate as spherical waves from the luminous source. Wave systems from countless luminous points can pursue their several paths, and intersect each other without hindrance. But when two waves intermingle, the molecular movements on which they severally depend must be compounded, for the same molecule cannot move forwards and also backwards at the same moment. Therefore, when the opposite phases of the undulatory movement are exactly counter-balanced, there is rest by mutual *interference*, while the coincidence of similar phases *amplifies* the resulting wave. One may observe these effects in water waves, but they are still more evident on the surface of mercury. If in an oval trough half filled with mercury one suddenly dimple the surface at one of the foci, the waves spread to the sides, and are reflected to and fro, producing a beautiful system of interference lines.

Luminous undulations give rise to similar though much less evident results, because of the extreme shortness of the waves, and the invisibility of the medium in which they are propelled. The interference of light may be shown by several methods. The most intelligible is one of those devised by Fresnel, in which a system of waves of red or green light slightly diverging from a common source is received on two closely adjacent straight-edged plain mirrors of steel, or of plate-glass blackened behind, and inclined towards each other at an angle of 180° or less (fig. 2, M, N). The waves falling on the inclined surfaces are reflected in two systems that intersect each other at an angle suitable for the production of interference phenomena. When the light falls on a screen of ground glass there is a bright central band, with a fringe of alternate dark and light bands on each side, the dark bands arising from the coincidence of opposite phases, the light bands from the coincidence of similar phases of the two sets of waves.

The phenomena produced by Fresnel's mirrors arise simply from the interference of luminous waves; those produced by a slit arise from the *diffraction* as well as the *interference* of the wave motion. Diffraction is not peculiar to light. All undulatory movements may be diffracted. The *principal wave* that spreads from a point of disturbance on the surface of a liquid is the resultant of an infinite number of *elementary motions* of the molecules. Every molecule implicated in the spreading wave successively becomes a centre from which an elementary wave system radiates. But in the mutual

[1] These phenomena may be more simply, though less clearly, shown by the ordinary method of placing a slit in a piece of black cardboard or paper before a lamp, and looking at it through a line drawn with a needle across a slip of smoked glass. The blue diffraction bands cannot be seen, however, unless the lamp is completely shaded to cut off all diffuse light.

intermingling of the elementary waves there is an infinite labyrinth of interference and reinforcement that results in the formation of the principal wave.

Fig. 2.—Fresnel's experiment with "interference mirrors" M, N. Luminous pencil of monochromatic light diverging from the focus of a lens (S); *s*,*s'*, virtual foci of the cones of rays reflected from the mirrors; *a*,*a'*, *d*,*d'*, *e*,*e'*, coincidence of similar phases of undulation strengthening the light; *m*,*m'*, *n*,*n'*, coincidence of opposite phases producing darkness. (This fig. from Ganot's *Physique*, 20th ed., errs in having the luminous point S so near and so high that no light could reach mirror M.)

When a screen with a wide slit in it is placed across a trough of water or of mercury, and waves propelled against it, a fraction of each wave passes on through the slit, but in so doing gives rise to a new system of secondary waves spreading in arcs of circles from each margin of the slit into the space protected from the principal waves behind the screen, and also across the path of the principal waves that have passed on through the slit. The secondary waves arise at the slit from the elementary motions of the on-passing portion of the principal waves being no longer restricted laterally by the elementary motions of the arrested portion of the wave.

The undulations of light behave in a similar manner. The so-called "rays" are merely the paths pursued by the undulations as they travel from a luminous point. The principal waves (fig. 3, *p*)

Fig. 3.—*p*, principal wave arriving at a slit in a screen, *s*; elementary undulations in principal wave, *e*.

result from an infinitude of *elementary* wave systems (*e*) radiating from every molecule of the ether. If the so-called rays are divergent, the principal wave front is convex; if they are parallel, the wave front is flat. When a beam, it matters not whether of divergent or

Fig. 4.—Schematic representation of effect of slit *ab* in a screen *s* on principal waves *p* of divergent light; *d*, diffracted waves. Only those diffracted from margins of slit are shown; similar diffracted waves proceed from every point in whole width of slit. (Original drawing.)

of parallel light, impinges on an opaque screen (*s*) with a fine slit, the principal waves pass on through the opening, but owing to their

fracture the elementary motions of the on-passing waves immediately give rise to new systems of secondary or *diffracted* waves, *not merely at the margins of the slit where the fracture occurs, but throughout its entire width.* Every molecule of the vibrating ether in the slit is affected, and helps to form diffracted waves, while at the same moment helping to transmit the principal waves. The paths or rays of the diffracted waves diverge in all directions from the slit. From every point in its whole breadth they spread bilaterally into the geometrical shadow of one side, and across the principal rays into the shadow on the other side, so that on each side of the slit there are diffracted rays that have travelled through different small distances from various points in the slit (fig. 4, *d*). When the decussating waves are half a wave length behind each other, there is darkness from interference, and when similar phases coincide there is reinforcement, so that alternate dark and light bands are produced by the diffracted rays. Since the undulations of green are longer than those of blue light, it follows that the coincidence of similar and of opposite phases of undulation must render the diffraction bands broader with green than with blue or violet light, and still broader with red light. The diffracted rays also produce interference effects with the principal rays (*p*), but feeble monochromatic lights (preferably green) is required to show them.

I have thus briefly sketched the principles involved in the diffraction of light, in the hope that those of you who have not had the opportunity of previously studying these subjects may be enabled to follow the gist of what I have still to say.

Diffraction phenomena may be beautifully shown with a series of parallel slits termed a *grating*. You will find Abbe's grating under a microscope on the table. It is a cover-glass silvered on one side, and the silver film then cut into equi-distant lines with a diamond. The silvered surface is inverted and cemented with balsam to a slide. There are two sets of lines, the intervals between them in one set being 15 micro-millimetres (fig. 5, *a*), and only half as wide in the other set (*b*). The objective used is Zeiss *aa*, as recommended by Abbe; with a No. 3 eyepiece it magnifies about 50 diameters. With transmitted light you simply see a number of clear lines in a dark field, each line being a fine slit in the silver film. The grating may be used to show diffraction fringes, and also to illustrate Abbe's theory of the microscopic image of such lines.

Fig. 5.—Abbe's grating. The lines at *a* are 15 micros. apart, those at *b* are 7·5 micros. apart.

If you place a very small aperture of a stop diaphragm on a level with the upper surface of the stage, and focus the broader spaces of the grating (*a*), and then lower the lens to focus the margin of the aperture in the diaphragm, you of course lose sight of the grating

slits no longer in focus, and the margin of the diaphragm is remarkably sharp considering that it is seen through the grating. You will see a bright round disc due to the principal rays of the aperture, with a series of coloured diffraction fringes on each side overlapping each other and the central disc, and extending at a right angle to the lines of the grating (fig. 6, A). Gradually increase the distance between the diaphragm and the grating, and at the same time lower the lens to keep the margin of the aperture sharply in focus, and you will find the diffraction fringes more laterally (B), and eventually become separate discs, if the aperture is sufficiently small, and sufficiently far from the grating. The diffraction discs no longer overlapping show each a pure spectrum, the violet being always on the side nearest the principal disc. If you now bring the finer grating (fig. 5, *b*) over the aperture, the diffraction discs move still further apart (fig. 6, D). Using the lens I have mentioned, you will probably find that the diffraction discs have been thrown so far aside that only the inner one of each series is now visible in the field (D, *d'*). Evidently *a still finer grating could throw all the diffraction discs out of the field.*

Fig. 6.—Diffraction phenomena produced by Abbe's grating with ordinary light. Aperture of diaphragm seen with Zeiss obj. *aa*, and oc. No. 3; *p*, principal; *d*, diffracted discs; corresponding discs indicated by ′, ″, ‴; A.B.C., aperture seen through grating (fig. 5, *a*); D, the same seen through finer grating (fig. 5, *b*). (*Drawn from the object.*)

I have now to explain Abbe's theory of the formation of the microscopic image of the grating. You will find it easiest to perform the experiment in proof of his theory with monochromatic light. Therefore, place a plate of "signal" green glass on the stage under the grating. Focus the broader spaces (fig. 5, *a*), and place the same small aperture of the diaphragm sufficiently near to illuminate the field diffusely, but not too brightly. On removing the eyepiece and

looking down the tube with the eye shaded from collateral light, you will see a row of small green discs crossing the field at a right angle to the slits of the grating. The discs will be so close together that confusion is apt to arise. It is well, therefore, to bring the finer grating (*b*) under the lens, and a central disc due to the *principal or dioptric* rays will be seen in the centre, with two diffraction discs on each side of it (fig. 7, *a*). Abbe has shown that the eyepiece reunites the principal and diffracted rays, and thus produces the microscopic image. You will find a slot in a collar intercalated above the objective, and if you place in it a diaphragm with a slit in the middle just large enough to permit one of the circular beams to pass, you will find on replacing the eyepiece that the position of the grating is marked by a diffuse light band in which no lines are visible, even though the slit is arranged to allow the principal or dioptric beam to pass (fig 7, *b*). But if a wider slit, capable of admitting two of the discs, be substituted, the lines are visible, because the reunion of two sets of rays is necessary for the formation of their image. The slit may be placed to permit the principal beam and portions of the inner diffracted beams to pass (fig. 7, *c*), or the principal beam and

a *b* *c*

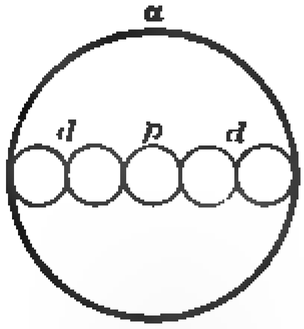


Fig. 7.—To illustrate Abbe's theory of formation of microscopic images.

a. The finer grating (fig. 4, *b*), illuminated with small aperture of diaphragm same as that used in fig. 5, is sharply focussed and eyepiece then removed. Dioptric beam *p*, and four diffraction beams *d*, seen on looking down tube.

b. A diaphragm with slit introduced above lens, cutting off all the diffraction beams, and allowing only dioptric beam to pass. On replacing eyepiece, no lines of grating visible.

c. A wider slit allowing dioptric and one diffractive beam or portions of two diffraction beams to pass. On replacing eyepiece lines are visible. (*Drawn from the object.*)

one of the inner diffracted beams may be taken, or the principal beam and the diffraction beams on one side of it may all be excluded, and the lines still be visible, provided the remaining two diffraction beams are permitted to pass to the eyepiece. The resolution of the lines, however, is most complete when all the beams are utilised in producing the image on the eyepiece.[1]

[1] One may perform this experiment in a slightly different way by removing the diaphragm and placing a lamp with a flat wick at some distance from the microscope, with the edge of the flame turned towards it, the principal and diffracted rays produce oval images when the eyepiece is removed, and by placing the lamp sufficiently far away the beams can be separated to a greater extent than when the diaphragm is used. Of course, if the coloured glass is removed the diffracted beams form spectra, while the principal beam is mainly white.

From these experiments it follows that for the resolution of the lines of the grating the principal or dioptric rays are insufficient without the addition of diffracted rays. I intentionally omit further detail[1] regarding these experiments, for I have stated the main points which will carry me to the explanation of the limitation of microscopic vision. It follows from what I have stated that if the lines of a grating are so close that they throw the principal and diffracted beams so far apart that both cannot appear in the field at the same time, the resolution of the lines would be impossible, because one beam of rays is insufficient. It follows that a wide-angled lens must admit a pair of more divergent beams from such an object than would be possible with a lens of small angle, and must therefore have a greater *resolving power*. It also follows that violet light must, because of its shorter waves, be able to resolve what green and red light cannot, for we have seen that with blue or violet the interval between the principal and diffracted beams is narrower than with green or red light; therefore a grating fine enough to throw the diffracted rays of red or green light out of the field could still be resolved by violet, and still more by ultra-violet light, provided at least a portion of the inner diffracted beam is not thrown from the field. Hence it is that photography can, by utilising violet and ultra-violet light, render visible what cannot be seen without its aid. On this account photomicrography is destined to play an increasingly important part in microscopy, and the apochromatic lenses of Abbe have already greatly facilitated the practice of a method hitherto much neglected, because of the difficulty in finding the focus of the chemical rays with the old lenses.

Gentlemen, it would be difficult to prophecy what new achievments may mark the fourth century of the compound microscope, but it is scarcely to be expected that they can be so remarkable as those of the century now closed, in which science has advanced so rapidly, and has pursued so many paths leading to the attainment of possible results, and leaving superlative difficulties for the future.

[1] For further detail of Abbe's experiments see "Observations on Professor Abbe's Experiments, &c.," by J. W. Stevenson, F.R.A.S., *Monthly Microscop. Journ.*, vol. xvii. p. 82.

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